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THE CURVE OF COMPRESSION IN THE STEAM ENGINE.

By J. C. HOADLEY.

Whoever has had occasion to examine carefully the curves of indicator diagrams, has probably found that none of the formulæ given by Rankine and others, for curves of expansion, represent, with even tolerable accuracy, the compression curves actually drawn by the instrument.

Clearance (including "waste room") being accurately known, the indicator in good order, the scale of the spring correct, and the diagram satisfactory; the curve of compression will always be found steeper than the curve of expansion; higher at the upper end, and lower at the lower end, than any normal or theoretical curve ever employed to represent expansion curves. There are, as it seems to me, obvious reasons for this. Steam, during its expansion in the steam engine, performs work, and the heat energy converted into kinetic energy, must result in condensation of steam, and in a consequent depression of the curve at its lower end. This condensation is generally counteracted, often far exceeded, in the case of engines with unjacketed cylinders, especially when running at low rotatory speed, by re-evaporation of water condensed during admission. Professor Rankine's adiabatic curve, or curve of no heat transmission, is adapted to the hypoth-

esis that just enough heat will be supplied by the jacket to prevent the condensation of vapor; so that while doing work by expansion against a moving resistance, the steam in the cylinder will be constantly maintained in the condition of "dry, saturated steam." This hypothesis is well sustained by facts obtained from steam-jacketed cylinders running with a rotatory velocity of 125 to 300 revolutions per minute. At the lower speed, 250 reciprocations per minute, or over 4 per second, the actual curve is very little indeed above the adiabatic, at its lower end. With the higher speed, 600 reciprocations per minute, 10 per second, the adiabatic curve represents the actual curve with great accuracy.

But in curves of compression, the case is quite different. Work is here converted into heat; and some water present in the steam must be evaporated, adding to the tension. Heat transmitted from the steam jacket tends to accentuate, not to disguise this effect. I had long desired a formula which should fairly represent this curve; which would answer for compression curves, as well as the "adiabatic" does for curves of expansion; and having obtained from one of my engines, at the Centennial Exhibition, some diagrams of unusual delicacy and accuracy, with very early closure of the exhaust, and pretty high boiler pressure (145 above the atmosphere), I attempted the solution of the question, by a method of which I here propose to give a detailed account. The diagram taken from the end of the cylinder nearest to the crank was first tried, and gave results so encouraging that I proceeded to apply the same method to the diagram taken from the end of the cylinder farthest from the crank, using still greater care in every step of the work. This diagram is to be preferred to that taken at the other end, as it is exempt from the disturbing influence of the piston-rod, no inconsiderable surface condenser, being exposed half the time to the air of the engine room, not to dwell on possible leakage at the stuffing box. This diagram was taken Aug. 8, 1876, preparatory to a public trial made a few weeks later, by the Judges of Group XX and experts appointed by the Centennial Commission.

The engine, a semi-portable, or "entire engine," had 14·5 inches diameter of cylinder and 20 inches stroke. The speed, as then regulated, was 123 revolutions per minute. The clearances, as then adjusted, were: end nearest to the crank, ·0794; at the end farthest from

G

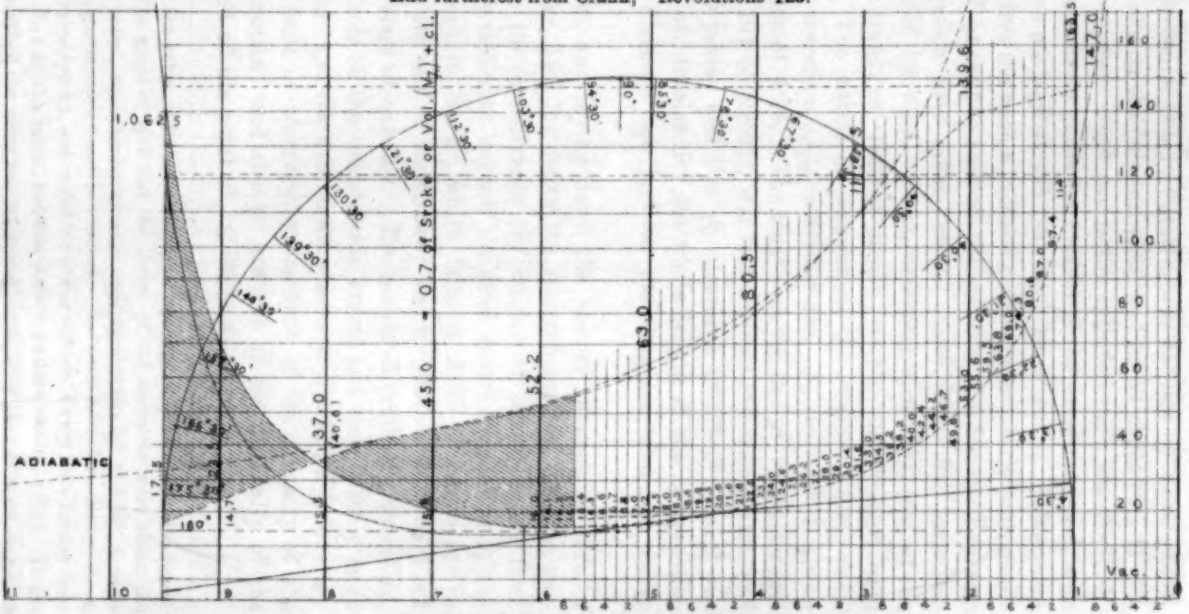
DIAGRAM TAKEN AUGUST 8TH, 1876.

Portable Engine No. 1270, the J. C. HOADLY Co., $14\frac{1}{2}''$x20″, tested at Centennial Exhibition, September 7th, 1876.

Boiler Pressure, 1451 14.7=159.7. Scale of Indicator Spring, 56 lb. per inch.

L=$\frac{13.6}{4}$=4.9 in. Expansion=$\frac{4}{5.1315}$=3.97. Virtual Cut-off=.2519. Clearance .1161.

End furtherest from Crank, Revolutions 123.



crank, ·1161 of volume swept through by the piston, of course taking into account the volume of piston rod.

The boiler pressure, as before stated, was 145 lbs. by steam gauge. The friction brake on the balance wheel was set at about 72·7 H P., and the effective power developed in the cylinder was about 80 H. P. The cut-off was entirely under the control of the governor; and, with a boiler pressure so high as 145 lbs., took place early. Subsequent adjustment, before the trial, equalized a little more nearly both clearance and cut-off at the two ends of the cylinder. When the diagrams under consideration were taken, virtual cut-off (total fill, including clearance, divided by total volume, including clearance) was, at the end nearest to crank, at ·1949 of stroke; at the end farthest from crank, ·2811. The ratios of expansion, the reciprocals of these numbers, were therefore $\frac{1}{1949} = 5{\cdot}1308$ and $\frac{1}{2811} = 3{\cdot}5574$, giving a mean expansion of 4·34. The length on the line of volumes equal to clearance (·1161 of stroke), was laid off from the dead centre, and divided into 10 parts; and this $\frac{1}{10}$ clearance (·0116 of stroke) was made the unit of division for the whole length of the compression urve; these divisions are laid on the diagram, and are fairly accurate.

After division, and laying down the line of vacuum, or zero of absolute pressure, 14·7 lbs. below the atmosphere line, the next step was to measure the pressures, or the heights of the ordinates, from No. 11, the first ordinate beyond the dead centre (beginning at the end of clearance), to No. 60, which falls at ·4195 of return stroke = ·5805 before the end of the stroke; and is ·5937 — ·4195 = ·1742 short of the closure of exhaust. The measured ordinates, therefore, embrace the whole of the compression curve, and considerably more at the lower end; and the first measurement at No. 11 (V_{11}) is rather outside of the limit of accuracy, on account of the obliquity of the angle of intersection; and also on account of the proximity of the dead centre, and of the point of valve-opening.[1]

[1] The "lead" of the valve, or its actual width of opening at dead centre, was invariably 1-16 inch. The angle of lead and the throw of the eccentric were under the control of the governor; the angular advance varying between 30° and 90°, and the throw of the eccentric between 5 and 2·5 inches. The point of return stroke, therefore, at which the valve opened, was variable; at the earliest, a very little farther from dead centre than V_{11}; at the latest, extremely close to dead centre, (V_{10}). In the case under consideration, the valve was not opened until after the piston on its return stroke had passed V_{11}.

The method of investigation is by the differences of the logarithms representing the volumes, the serial numbers 1, 2, 3, etc., to 60; and the differences of the logarithms of the corresponding ordinates; the several differences of the latter series being divided by the corresponding differences of the former series, giving their ratio, or the Nat. tang. of the angle at the base. The mean of these ratios, care being taken to embrace none extending beyond the probable limits of curve, gives the exponent sought, for the whole curve, provided the curve can be fairly represented by the formula $P \propto - V^n$, to use Prof. Rankine's notation, or $\frac{V^n}{V_1^n} = \frac{P}{P_1}$, or P proportional to $\frac{1}{V^n}$.

This method is carried out numerically in the Table A, for 33 pairs of differences, $\overline{11, 12}$ to $\overline{45, 46}$, giving a mean value of $n = 1{\cdot}247$.

Again taking the differences $\overline{12 \text{ to } 45}$, we obtain $n = 1{\cdot}2366 = \frac{5}{4}$ nearly.

The same method is worked out graphically on diagram B, in which the abscissæ represent the logarithms of the numbers, $1 = 0{\cdot}0000$, $2 = 0{\cdot}3010$, etc., to 60, $= 1{\cdot}7782$; and the ordinates, the logarithms of the corresponding pressures as measured on the original diagram. *A B* gives the entire series, and is a graphical representation of Table A. The first measurement to be fully trusted, is as V_{12}. The number 12 being highly divisable, we can easily obtain other tests of the same construction, on other parts of the scale. At *a b*, for instance, we divide by 6, and so take every second ordinate; at a' b', dividing by 4, we take every third ordinate; at a'' b'', dividing by 3, we use every fourth ordinate; at a''' b''', dividing by 2, we use every sixth ordinate; and finally, taking the whole volume of the clearance as our unit, we get at a'''' b'''', only 5 of our measured ordinates, namely, V_{12}, V_{24}, V_{36}, V_{48} and V_{60}. These six curves are all mutually confirmatory. All show the same feature at the lower end, beyond the curve of compression, and all give the same angle, the natural tangent of which is the exponent sought. There is a little oscillation, best seen at *A B*, and *a b*, caused by the inertia of the reciprocating parts of the indicator; which first resist motion, then move a little too far, and then oscillate with diminishing amplitude.

The mean of all the ratios, $\overline{12, 13}$, to $\overline{44, 45}$, Table A, is 1·247. The ratio of the differences for the extremes of the series, $\overline{12, 45}$, is 1·2366. The difference between these two ratios is slight—only 4 *per cent.*, and they are extremely near to $1{\cdot}25 = \frac{5}{4}$, or the fifth power of the

Table A.

Portable Engine, No. 1270, the J. C. Hoadley Co., 14½″ × 20″, tested at the Centennial Exhibition, Sept. 7th, 1876. Diagram G, taken Aug. 8th, 1876. 145 lbs. gauge pressure in boiler. Compression curve. Cl. = ·1161, divided into 10 parts. The 10th ordinate is at dead centre.

Nos.	B.	C.	D.	E.	F.		
Volumes. V.	Logs. of Ordinates.	Difference of Logs.	Measured Absolute Pressures. P.	Logs. of Pressures.	Difference of Logs.	Ratios. $\frac{F}{C}$	
10	1·0000						Dead Centre, $= V_{10}$
		414					
11	1·0414		114·	2·0569			
		378			683	1·807	
12	1·0792		97·4	1·9886			
		347			491	1·415	
13	1·1139		87·	1·9395			
		322			382	1·031	
14	1·1461		80·6	1·9063			
		300			353	1·175	
15	1·1761		74·3	1·8710			
		280			322	1·150	
16	1·2041		69·	1·8388			
		263			340	1·293	
17	1·2304		63·8	1·8048			
		249			303	1·213	
18	1·2553		59·5	1·7745			
		235			294	1·251	
19	1·2788		55·6	1·7451			
		222			208	·937	
20	1·3010		53·	1·7243			
		212			271	1·278	
21	1·3222		49·8	1·6972			
		202			279	1·381	
22	1·3424		46·7	1·6693			
		193			239	1·238	
23	1·3617		44·2	1·6454			
		185			180	·973	
24	1·3802		42·4	1·6274			
		177			253	1·429	
25	1·3979		40·	1·6021			
		171			200	1·170	
26	1·4150		38·2	1·5821			
		164			234	1·427	
27	1·4314		36·2	1·5587			
		158			209	1·323	
28	1·4472		34·5	1·5378			
		152			193	1·269	
29	1·4624		33·	1·5185			
		147			188	1·279	
30	1·4771		31·6	1·4997			
		143			168	1·175	
31	1·4914		30·4	1·4829			
		138			190	1·377	
32	1·5052		29·1	1·4639			
		133			167	1·256	
33	1·5185		28·	1·4472			
		130			142	1·092	
34	1·5315		27·1	1·4330			
		126			147	1·167	
35	1·5441		26·2	1·4183			
		122			152	1·246	
36	1·5563		25·3	1·4031			
		119			122	1·025	
37	1·5682		24·6	1·3909			
		116			107	·914	
38	1·5798		24·	1·3802			
		113			147	1·301	
39	1·5911		23·2	1·3655			
		110			114	1·036	
40	1·6021		22·6	1·3541			
		107			156	1·458	
41	1·6128		21·8	1·3385			
		104			163	1·567	
42	1·6232		21·	1·3222			
		103			212	2·058	
43	1·6335		20·	1·3010			
		100			110	1·100	
44	1·6435		19·5	1·2900			
		97			112	1·154	$41·158 \div (33 - 45 - 12) = 1·247$.
45	1·6532		19·	1·2788			
		96			93	·968	
46	1·6628		18·6	1·2695			
		93			70	·753	
47	1·6721		18·3	1·2625			12 — 1·0792, and 1·9886
		91			72	·791	
48	1·6812		18·	1·2553			45 — 1·6532, and 1·2788
		90			123	1·367	
49	1·6902		17·5	1·2430			·5740 ·7098
		88			75	·852	
50	1·6990		17·2	1·2355			
		86			51	·593	
51	1·7076		17·	1·2304			and ·7098 ÷ ·5740 = 1·2366.
		84			51	·607	
52	1·7160		16·8	1·2253			
		83			26	·313	
53	1·7243		16·7	1·2227			
		81			26	·321	Exponent of V — n — 1·25 — $\frac{5}{4}$.
54	1·7324		16·6	1·2201			
		80			26	·325	
55	1·7404		16·5	1·2175			
		78			27	·346	
56	1·7482		16·4	1·2148			
		77			26	·338	
57	1·7559		16·3	1·2122			
		75			27	·360	
58	1·7634		16·2	1·2095			
		75			27	·360	
59	1·7709		16·1	1·2068			
		73			27	·370	
60	1·7782		16·0	1·2041			
		71					

fourth root, which is a very convenient number to use, even without logarithms, as the fourth root is easily obtained by extracting the square root twice, and this square root of the square root, multiplied by the original number, gives the fifth power sought.

I subjoin an example of the method employed for computing points in the curves from the exponent, $n = 1{\cdot}2366$.

V_{12}. Log. of $12 = 1{\cdot}0791812$, and its log. $= 0{\cdot}0330944$
" " $(1{\cdot}2366 =$ exponent, n, of $V) = 0{\cdot}0922292$

$0{\cdot}1253236$

The natural number corresponding to this logarithm is itself the log. of $V_{12}^{1.2366} =$ $1{\cdot}3345153$

$P_{12} = 97{\cdot}4$, and its log. $=$ $1{\cdot}9885590$

Constant log. $=$ (log. of $V_{12}^{1.2366} \times P_{12}) =$ $3{\cdot}3230743$

V_{13}. Log. of $13 = 1{\cdot}1139434$, its log. $= 0{\cdot}0468636$
" " $1{\cdot}2366$ $0{\cdot}0922292$

$0{\cdot}1390928$

Nat. number corresponding to this log. $=$ log. of $V_{13}^{1.2366}$ to be subtracted from constant log. $=$ $1{\cdot}3775038$

$P_{13} = 88{\cdot}22$, its log. $=$ $1{\cdot}9455705$

In the following table the curve is computed, from V_{12} to V_{45}, by the exponent $1{\cdot}2366$, starting with $V_{30} = 31{\cdot}6$, and using only 4 places of decimals in the logarithms; the ordinates being carried out only to one place of decimals. The pressure measured at V_{30} on the diagram, $= 31{\cdot}6$, is taken as a starting point because it is midway of the length of the curve, and so situated that all the conditions are favorable to the accuracy of the measurement, confirmed, as it is, by the measurements on both sides of it.

For the constant logarithm, we have:

V_{30}. Log. of $30 = 1{\cdot}4771213$, and its log. $= 0{\cdot}1694162$
" " $1{\cdot}2366$, $0{\cdot}0922292$

" " $V_{30}^{1.2366} = 1{\cdot}8266080 =$ Nat. No. of log. $=$ $0{\cdot}2616454$

$P_{30} = 31{\cdot}6$; its log. $= 1{\cdot}4996871$

log. $V_{30}^{1.2366} \times P_{30} = 3{\cdot}3262951 =$ Constant log.

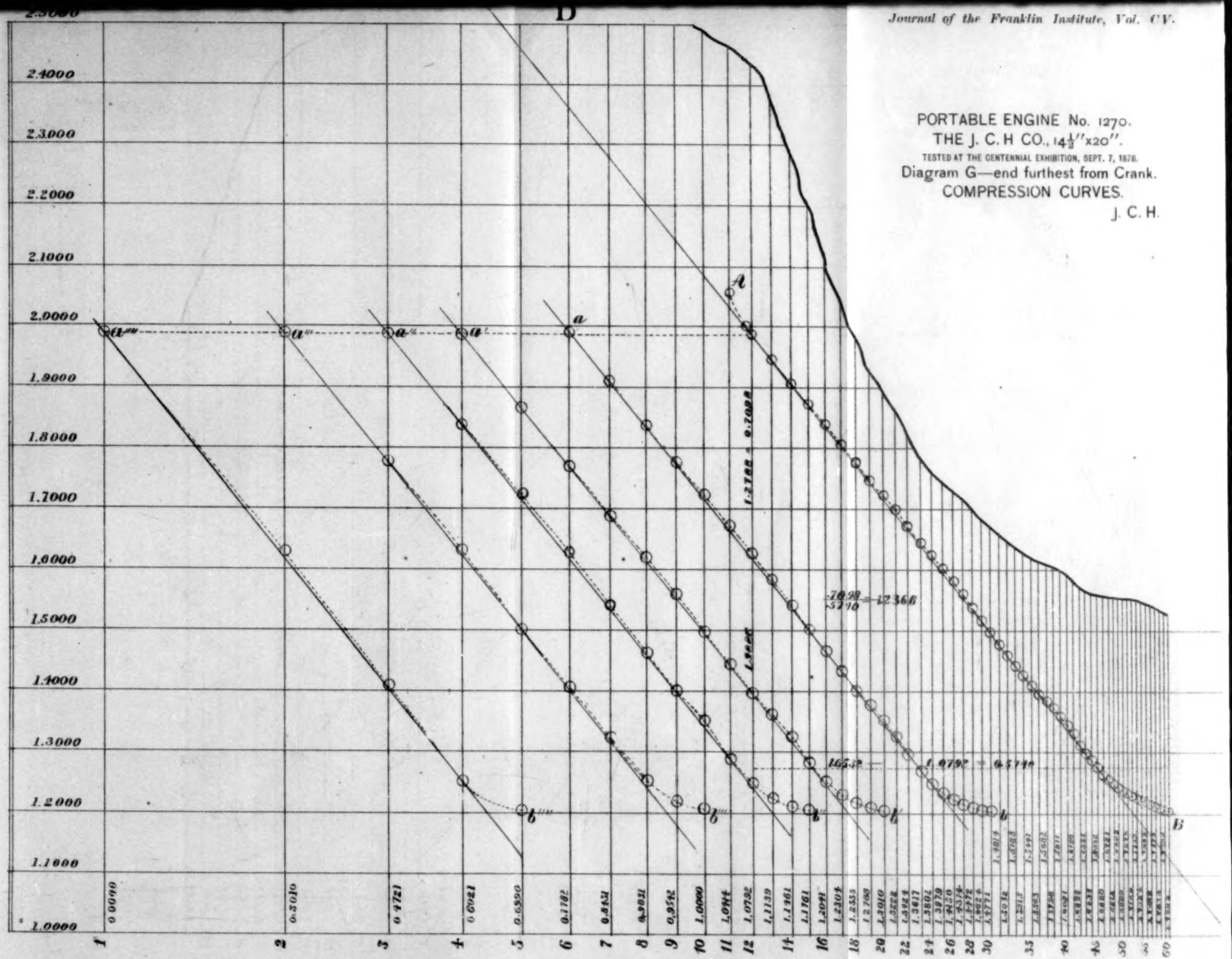

PORTABLE ENGINE No. 1270.
THE J. C. H CO., 14½"x20".
TESTED AT THE CENTENNIAL EXHIBITION, SEPT. 7, 1876.
Diagram G—end furthest from Crank.
COMPRESSION CURVES.
J. C. H.
D
A
B
a
a'
a''
a'''
b
b'
b''
b'''
2.4000
2.3000
2.2000
2.1000
2.0000
1.9000
1.8000
1.7000
1.6000
1.5000
1.4000
1.3000
1.2000
1.1000
1.0000
1.2788 = 0.7082
1.9797 = 0.5740
165.52
1 2 3 4 5 6 7 8 9 10 11 12 14 16 18 20 22 24 26 28 30 35 40 45 50 55 60

Table C.

Calculation of Compression Curve by the Formula $P \propto \frac{1}{V^{1.2366}}$

Starting at $P_{30} = 31{\cdot}6$.

A Numbers of Ordinates. Volumes. V.	B Logs. of Volumes. Logs.	C Logs. of the Logs. B. Logs.	D Logs C + a constant log. of $1{\cdot}2366 = 0{\cdot}0922$. Logs.	E Nat. Numbers of $D = \text{Logs. of } V^{1.2366}$ Logs.	F Logs. E subtracted from the constant Log. of $V_{30}^{1.2366} \times P_{30} = 3{\cdot}3263$. Logs.	G Nat. Numbers of F, computed Ordinates. Pressures.—Lbs. per square in.	H Measured Ordinates. Pressures.—Lbs. per square in.	I Differences. Lbs. per square inch.
12	1·0792	0·0331	0·1253	1·3345	1·9918	98·1	97·4	+ ·7
13	1·1139	0·0468	0·1390	1·3772	1·9491	88·9	87·	+ 1·9
14	1·1461	0·0592	0·1514	1·4171	1·9092	81·1	80·6	+ ·5
15	1·1761	0·0704	0·1626	1·4541	1·8722	74·5	74·3	+ ·2
16	1·2041	0·0807	0·1729	1·4890	1·8373	68·7	69·	− ·3
17	1·2304	0·0900	0·1822	1·5213	1·8050	63·8	63·8	0
18	1·2553	0·0987	0·1909	1·5520	1·7743	59·5	59·5	0
19	1·2788	0·1068	0·1990	1·5813	1·7450	55·6	55·6	0
20	1·3010	0·1143	0·2065	1·6088	1·7175	52·2	53·	− ·8
21	1·3222	0·1213	0·2135	1·6349	1·6914	49·1	49·8	− ·7
22	1·3424	0·1279	0·2201	1·6600	1·6663	46·4	46·7	− ·3
23	1·3617	0·1341	0·2263	1·6838	1·6425	43·9	44·2	− ·3
24	1·3802	0·1399	0·2321	1·7065	1·6198	41·7	42·4	− ·7
25	1·3979	0·1455	0·2377	1·7286	1·5977	39·6	40·	− ·4
26	1·4150	0·1508	0·2430	1·7500	·5763	37·7	38·2	− ·5
27	1·4314	0·1558	0·2480	1·7701	1·5562	36·0	36·2	− ·2
28	1·4472	0·1605	0·2527	1·7894	1·5369	34·4	34·5	− ·1
29	1·4624	0·1651	0·2573	1·8084	1·5179	33·0	33·	0
30	1·4771	0·1694	0·2616	1·8264	1·4999	31·6	31·6	0
31	1·4914	0·1736	0·2658	1·8442	1·4821	30·3	30·4	− ·1
32	1·5052	0·1776	0·2698	1·8612	1·4651	29·2	29·1	+ ·1
33	1·5185	0·1814	0·2736	1·8776	1·4487	28·1	28·	+ ·1
34	1·5315	0·1851	0·2773	1·8937	1·4326	27·1	27·1	0
35	1·5441	0·1887	0·2809	1·9094	1·4169	26·1	26·2	− ·1
36	1·5563	0·1921	0·2843	1·9244	1·4019	25·2	25·3	− ·1
37	1·5682	0·1954	0·2876	1·9391	1·3872	24·4	24·6	− ·2
38	1·5798	0·1986	0·2908	1·9534	1·3729	23·6	24·	− ·4
39	1·5911	0·2017	0·2939	1·9674	1·3589	22·9	23·2	− ·3
40	1·6021	0·2047	0·2969	1·9811	1·3452	22·1	22·6	− ·5
41	1·6128	0·2076	0·2998	1·9943	1·3320	21·4	21·8	− ·4
42	1·6232	0·2104	0·3026	2·0072	1·3191	20·9	21·	− ·1
43	1·6335	0·2131	0·3053	2·0198	1·3065	20·3	20·	+ ·3
44	1·6435	0·2158	0·3080	2·0324	1·2939	19·7	19·5	+ ·2
45	1·6532	0·2183	0·3105	2·0441	1·2822	19·2	19·	+ ·2
Algebraic sum of differences.....								2·3

Divided among 34 numbers, $\frac{2{\cdot}3}{34} = {\cdot}07$, or less than one-tenth of a pound per sq. in.

It will be observed that 19 of the computed ordinates fall below the corresponding measured ordinates; 9 fall above, and in 8 cases, including the starting point, P_{30}, the computed and measured ordinates are equal.

The aggregate of the minus differences is 6·5, which, divided by 19, gives about $\frac{1}{3}$ pound as a mean (·342). The aggregate of the plus differences is 4·2, which, divided by 9, gives less than $\frac{1}{2}$ pound (·467) as the mean. The algebraic sum of the differences is 2·3, which, divided by 34, gives the mean of the whole less than ·1 pound (·07).[1]

Let us now compute the same curve by the formula $P \propto \frac{1}{V^{\frac{5}{4}}}$, that is, substituting for the value of the exponent, $n = 1{\cdot}2366$, the simpler number $n = \frac{5}{4}$, starting as before at V_{30}, and with the same measured pressure, $P_{30} = 31{\cdot}6$.

Having at hand a list of modified logarithms from 1 to 100, in which each logarithm is increased by $\frac{1}{4}$ of itself, I find:

Log. $(30)^{\frac{5}{4}}$ =	1·8464016
Log. $P_{30} = 31{\cdot}6$,	1·4996871
Log. $V_{30}^{\frac{5}{4}} \times (P_{30} = 31{\cdot}6)$,	3·3460887, Constant log.

A comparison of the differences in column H, Table D, with the corresponding differences in column I, Table C, will show that the exponent $n = \frac{5}{4}$ represents the actual curve almost, but not quite as accurately as the exponent $n = 1{\cdot}2366$. The differences between these two computed curves are seen in column G, Table D. The principal difference is at the upper end, and if the 7 numbers, $\overline{12}, \overline{18}$, are omitted, the differences for the remainder of the curve will balance each other. The approximate exponent $\frac{5}{4}$ gives a curve a little steeper than the more accurate exponent 1·2366; a little higher at the upper end and a little lower at the lower end. Both approximate with reasonable accuracy to the measured curve. As curves of compression rarely (save in the locomotive) begin so early in the stroke, or extend

[1] The scale of the indicator spring is 56 lbs. to the inch. Therefore:

·342 lbs. = ·0061 in. = $\frac{1}{164}$ in.

·467 lbs. = ·0083 in. = $\frac{1}{120}$ in.

·07 lbs. = ·0013 in. = $\frac{1}{787}$ in.

Table D.

Calculation of Compression Curve by the Formula $P \propto \frac{1}{V^{\frac{5}{4}}}$,

Starting at $P_{30} = 31{\cdot}6$; and Comparison of this Curve with the Curve Computed in Table C, and with the Measured Curve.

Volumes. V.	Logs. of $V^{\frac{5}{4}}$. Logs.	Logs. of $V^{\frac{5}{4}}$ subtracted from constant 3·3461.	Ordinates			Differences.	
			By $n = \frac{5}{4}$.	By $n = 1{\cdot}2366$.	By Measurement.	D, E.	D, F.
A	B	C	D	E	F	G	H
12	1·3490	1·9971	99·3	98·1	97·4	+ 1·2	+ 1·9
13	1·3924	1·9537	89·9	88·9	87·	+ 1·0	+ 2·9
14	1·4327	1·9134	81·9	81·1	80·6	+ ·8	+ 1·3
15	1·4701	1·8760	75·2	74·5	74·3	+ ·7	+ ·9
16	1·5052	1·8409	69·3	68·7	69·	+ ·6	+ ·3
17	1·5381	1·8080	64·3	63·8	63·8	+ ·5	+ ·5
18	1·5691	1·7770	59·9	59·5	59·5	+ ·4	+ ·4
19	1·5984	1·7477	55·9	55·6	55·6	+ ·3	+ ·3
20	1·6263	1·7198	52·5	52·2	53·	+ ·3	— ·5
21	1·6528	1·6933	49·4	49·1	49·8	+ ·3	— ·4
22	1·6780	1·6681	46·6	46·4	46·7	+ ·2	— ·1
23	1·7022	1·6439	44·0	43·9	44·2	+ ·1	— ·2
24	1·7253	1·6208	41·8	41·7	42·4	+ ·1	— ·6
25	1·7474	1·5987	39·7	39·6	40·	+ ·1	— ·3
26	1·7687	1·5774	37·8	37·7	38·2	+ ·1	— ·4
27	1·7892	1·5569	36·0	36·0	36·2	0	— ·2
28	1·8089	1·5372	34·5	34·4	34·5	+ ·1	0
29	1·8280	1·5181	32·9	33·0	33·	— ·1	— ·1
30	1·8464	1·4997	31·6	31·6	31·6	0	0
31	1·8642	1·4819	30·3	30·3	30·4	0	— ·1
32	1·8814	1·4647	29·2	29·2	29·1	0	+ ·1
33	1·8981	1·4480	28·1	28·1	28·	0	+ ·1
34	1·9143	1·4318	27·0	27·1	27·1	— ·1	— ·1
35	1·9301	1·4160	26·1	26·1	26·2	0	— ·1
36	1·9454	1·4007	25·2	25·2	25·3	0	— ·1
37	1·9603	1·3858	24·3	24·4	24·6	— ·1	— ·3
38	1·9747	1·3714	23·5	23·6	24·	— ·1	— ·5
39	1·9888	1·3573	22·8	22·9	23·2	— ·1	— ·4
40	2·0026	1·3435	22·1	22·1	22·6	0	— ·5
41	2·0160	1·3301	21·4	21·4	21·8	0	— ·4
42	2·0291	1·3170	20·7	20·9	21·	— ·2	— ·3
43	2·0418	1·3043	20·2	20·3	20·	— ·1	+ ·2
44	2·0543	1·2918	19·6	19·7	19·5	— ·1	+ ·1
45	2·0665	1·2796	19·0	19·2	19·	— ·2	0
Algebraic sums of differences.....						+ 5·7	+ 3·4
Mean differences.....						+ ·17	+ ·1

Note.—The greatest difference + 2·9 lbs. = ·0518 in., say $\frac{1}{20}$ in. The mean ·17 lb. = ·003 = $\frac{1}{330}$ in. The mean, ·1 lb. = ·0018 = $\frac{1}{560}$ in.

to so great a height, as in the diagram here under consideration, the formula $P \propto \frac{1}{V^{\frac{5}{4}}}$ will generally be found sufficiently accurate for cards from steam-jacketed cylinders, with not less than 120 revolutions per minute, 4 reciprocations per second.

But convenient as this formula is, and closely as it represents compression curves in engines similar to the one from which this diagram was taken, it will always be found more satisfactory to deduce a special formula for each engine, or each class of engines, from accurate diagrams, carefully divided (accurate knowledge of the clearance being a necessity), and the object of this paper will be best accomplished if it shall be found of any assistance to the engineering profession in the investigation of such curves. I will only add the obvious remark, that the method here set forth is equally applicable to expansion curves, and will in all cases give the best possible representation of any given curve which can be obtained by any formula for a curve of the hyperboloid order.

ON THE RELATION OF MOISTURE IN AIR TO HEALTH AND COMFORT.[1]

By Robt. Briggs, C.E., Cor. Mem. Am. Inst. of Architects, etc.

It may be accepted that the most pleasant condition of the air, in our portion of the globe, will be found to exist on a fair day in early summer, when the temperature ranges from 62° to 68° Fahr., and the moisture present in the air is from 85 to 80 per cent. of saturation. On a day like this, no thought of the weather is taken, and the passage of the conversational compliment of a "fine day" becomes a needless reminder, to be accepted without discussion or thought. Admitting this proposition as a fact, it is the purpose of this paper to show that in our climate this summer condition of relative heat and moisture is not desirable, or even attainable, at other seasons, in the ventilating or heating of occupied places. And in presenting this view to the American Society of Architects, I do so with a full knowledge that it does not accord with the opinion of most American

[1] Paper read before the Am. Institute of Architects, at Boston, Oct. 18th, 1877.

writers on the subject of ventilation, who have derived their information and their arguments mainly from the study of English and French books, and have only endeavored to reconcile the data found in these to American wants and practice. Even Wyman, who is by far the most original as an observer, as well as the most thorough as the collator of information from all sources, hardly makes the distinctive effect of our low temperature, combined with a comparatively lower dew point, sufficiently evident.

Except one investigates the relation of moisture to temperature of air in the two countries, it is impossible to reconcile our facts with the statement of good foreign authorities,[1] that 56° is comfortable, and 62° is warm in living rooms in mid-winter; while the American shivers with cold at 70°, and is not overwarmed at 76° in the apartments of his own dwelling, although clad in the thickest of underclothing. Investigation, however, shows that the deprivation of heat from the person is more due to evaporation from the lungs or throat, and from the skin, than from heat otherwise dispersed; whether carried off by the breath, imparted to the air, or radiated to surrounding objects. And further investigation will show that the hygrometric state of the air has so much effect in inducing or retarding evaporation, as to make 56° Fahr. in the West and South of England, in Ireland and in Normandy, sensibly as warm as 80° in Canada or Minnesota at the same season. A brief statement of the difference of climatic condition of England and of America may show why we cannot import English theories of ventilation and heating, and apply them at once, without modification, to American residences. The English climate affords nearly eight months in every year, when the thermometer ranges between 40° and 60° in the shade, with a dew point so high, that it is a pleasure to exercise in the invigorating air; one month of 60° to 80°; and three months from 25° to 50°; there

[1] The comfortable warmth of air indoors is given by various authorities, as follows: Peclet, "Traité de la Chaleur," gives 15° Cent., 59° Fahr. Morin, "Etudes sur la Ventilation," for nurseries, schools, etc., 59°; hospitals, 61° to 64°; theatres, assembly halls, etc., 66° to 68°! Tredgold, "Principles of Warming and Ventilating, etc.," 56° to 62°. Reed, "Illustrations of the Theory and Practice of Ventilation," 65°. Hood, "Treatise on Warming Buildings, etc.," inferentially 55° to 58°. Parkes, "Manual of Military Hygiene," 48° to 70° (this author has encountered the difficulty of naming a fixed temperature, and avoids the issue). Box, "Practical Treatise on Heat," 62°. Others might be quoted, but these are amongst the best authorities on Heating and Ventilation.

being no term, except a part of the one month of heat reaching to 80°, when any person cannot, with suitable clothing, enjoy the open air. While in America there is scarcely one month (or 30 days) out of the year, having an average temperature of 50° to 75° (which temperatures, from the difference of dew point, correspond sensibly with 40° to 60° in England); and there are three months of 75° to 90°; three months of 30° to 50°; and five months of excessive variation of temperature of from 0° to 50°. During the three hot months, and also during most of the five cold, open air exercise to those whose avocations are within doors, is, if not impossible, at least very uncomfortable, however clad or covered. Anyone, who is called upon to endure the fervid summer heat, or who can habituate himself to the inclemencies of our arctic winter, will not suffer great discomfort, nor experience much injury to his health therefrom; but the weak and tender—the merchant from his counting house, the student from his closet, the workman from the shop, the women and children of the house—cannot acquire the endurance or the habit, and must shelter and protect themselves.

This preamble to the subject has been intended to impress the fact that its consideration must be on its own merits, and not through the light thrown upon it by general writers, that its investigation shall be original from physiological considerations, and not based upon authorities.

§ Comfort, if not existence, depends upon a constant loss of heat from the person. The internal natural warmth of the body is very nearly 100° Fahr., regardless of the heat of the external air, and the personal comfort which proceeds from the temperature and humid condition of the air, proceeds from the cooling effect which must then occur with constancy and regularity, and yet not so fast as to produce the sensation of cold. The origin of the natural heat is well established. There is inhaled by each adult in comparatively still life, each 3 to 4 seconds, from 30 to 40 cubic inches of air, at such temperature as may exist at the place, with extreme differences of temperature ranging from $-40°$ to $+140°$ Fahr., and with extremely variable proportions of humidity, from the point of saturation on the one hand to that of nearly an anhydrous air on the other. The practical extremes in our country are from little below zero to about 100°, accompanied also with great variation of humid condition. A portion of the oxygen of the inhaled air is consumed in the system; and the exhala-

tion, which follows each inhalation, emits about 4 per cent. of carbonic acid, and 1½ per cent. of vapor of water. Two or three grains of carbon are consumed in the system each minute, giving out 3¾ to 5¾ units of heat; the unit of heat being the equivalent to a pound of water heated 1° Fahr. It is the dispersion of this heat which establishes the sensation of comfort. Modern theory has established the convertibility of heat to work or power, and some portion of the heat evolved by the air of respiration will have been converted into labor or effort, but far the greatest portion will have been utilized in preserving the temperature of the body from the losses by evaporation of moisture, by conduction and by radiation. One portion of the loss is readily estimated. The breath is inhaled at whatever temperature and humidity may subsist at the place, but is exhaled at all times at 90° (when the temperature of the air is not above that degree), and it is saturated with moisture at that temperature. If it is supposed that the temperature of the external air is 62°, and the dew point 54° (= 65 per cent. humidity), from 0·35 to 0·56 unit of heat will have been expended in evaporation of moisture in the lungs and throat, and 0·10 to 0·17 unit of heat in imparting heat to the exhaled air each minute. About 3½ times as much heat will have been expended in supplying the moisture, as in heating the air. The loss of other portions of heat cannot be as definitely estimated. It is evident that it must mainly be dispersed from the skin, and it is pretty certain that a large, if not much the larger, portion must pass off in insensible perspiration, which will be greatly affected by the condition of humidity of the surrounding air. Here clothing becomes an important element. We protect ourselves against the inclemency of winter, or the heat of summer, by coverings more or less non-conducting or non-radiating, leaving but a small portion of the person unprotected by direct exposure. An almost instinctive preference is given by all people, of all times, and at all places, for porous clothing; even the skins which clothe the inhabitants of the coldest regions, although quite impervious to moisture and to currents of air, are very open for the passage of vapor of water, or of diffused gases. Evaporation, and consequent cooling of the skin, takes place in great measure, or is influenced by the relative vacuum which the quantity of vapor present in the air establishes. The transfer of vapor is then one of diffusion, and follows the law of diffusion of gaseous bodies. A partially anhydrous air, external to the clothing, is a partial vacuum

to the vapor of 90°, existing in ducts of perspiration, and this vapor rushes towards the vacuity without encountering the resistance of any circulation, and meets no considerable obstacle in the porous coats and overcoats. It is in this way possible to explain why, in mid-winter, with the room from 65° to 70°, heavy underclothing is not only endurable, but necessary. The overcoat may be removed on entering the well warmed house, but no discomfort follows from the retention of warm garments, that, with a summer condition of air of the same temperature, would be oppressive. We sleep in rooms, which, if not warmed to the full heat of our living rooms, have yet the "temperate" point of indication by the thermometer, and in this case enjoy a pile of bed clothing, which would be suffocating in weather of the same natural temperature. The American requirement of comfortable drawing room clothing is strikingly different from that of England. The ladies' English drawing room dress is an impossibility in America. Even the rigorous laws of fashion fail to conform themselves in this case, and yet our American drawing rooms are *hotter* than the English ones.

What proportion of the heat generated by formation of carbonic acid to be dispersed from the body after taking out what is abstracted by exhalation and by labor of work or animal life, is expended in vaporization of water, is of course doubtful. Some authorities give 2 to $2\frac{1}{2}$ lbs. of water to be evaporated, each day, by insensible perspiration. These quantities would give (nearly) 2000 to 2500 units, or $1\frac{1}{2}$ to $1\frac{3}{4}$ units of heat per minute, and, together with the quantity of heat dispersed in breathing (on the previous supposition), account for one-half of the heat produced; leaving one-half the heat to be dispersed in work, life, or conduction to air, or radiation to other bodies. These authorities quoted are, however, English, and it is uncertain what quantity of moisture is evaporated from the skin in heated rooms in mid-winter in our climate.

It is probable that in still air, with the person in repose, the transfer of heat, either from the person or the clothing, whether from radiation or from conduction, is nearly equal; but in any current of air or movement of the individual, the effect of conduction will much exceed that from radiation. It should be remembered, however, that a current of air always exists about any person. The comfortable temperature of the air being lower than that of the person, there is established, by the heat imparted to the air by the person, an ascen-

sional current surrounding and enveloping him, sufficiently defined to be measurable by a delicate anemometer, which is effective in augmenting considerably the convection of heat over what would occur in entirely still air. Assuming any comfortable temperature for air between 60° to 80°, the exhalations of breath by virtue of extra temperature and the presence of vapor to saturation, notwithstanding the addition of some carbonic acid gas of greater density than that of the air, are still so much lighter than the air as to ascend at once after the directional impulse from the mouth or nostrils will have expended itself, which, when the act of breathing has its normal force, and is not made violent by running or exertion, occurs within two feet.

In all cases the sensibility to loss of heat, whether from the breath as exhaled moisture or heated air, or from the person as evaporation from the skin, or as conduction to air, or by radiation to cooler objects, this sensibility, I say, varies in the several regards with different persons, with different races or nations, and above all, with the habits from business pursuits or occupations, or the customs or fashions of the place of living; any of which causes may and will have established a regime in each individual, and their comfort will depend upon conformity thereto. The occupation, business or habits of individuals as regards their labor or exercise, both when at labor or exercise, or when at rest, cause much discrepancy in demands for heat. In the coldest and dryest day, few young persons can fail to warm themselves to the point of comfort in skating—many of the trades demand special temperatures for the workmen, some requiring special temperature and moisture condition of the air for the work—to which temperature and condition the workmen must conform.

There are three means provided for the healthful dispersion of animal heat into the atmosphere; the first is radiation to surrounding colder objects; the second, conduction to the atmosphere, which, for comfort, must be sensibly cooler than the body, and the third is evaporation from the moist surfaces of the lungs, throat, and the roots of the pores of the skin. The first of these means, to the clothed person at least, is comparatively ineffective, while the relative quantities of heat which may be eliminated in any given time or locality, by the last two, will probably be found nearly equal in an atmosphere of about 70° temperature and 65 to 70 per cent. of humidity. In all cases of *excess* of animal heat, the animal, and mankind as an animal,

find relief in evaporation of water secreted in the system, showing that vaporization is the ultimate means of dispersion of heat.

Even the races of animals exhibit diversity of natural methods of dispersing the surplus animal heat. Thus the dog obtains relief through the breathing functions, and extends the surface of evaporation by exposure of the tongue, while the horse breaks out into profuse perspiration of the skin.

The relation of what is indicated by the sense of cold or warm to definite temperature with varied proportions of humidity, may be examined at this stage of the argument. Considering a nearly saturated atmosphere, it will be found that its effects differ with the temperature altogether. Such an atmosphere at from 35° to 50° is found to be intolerably chilly, and although evaporation may be checked, and this source of loss of heat be removed, yet the conductive and radiating value of the vapor in the air is now elevated enormously. The cooled surface of the cuticle absorbs the natural heat of the skin, and represses the evaporation of secretions almost entirely. An actual transfer of heat from the skin to the vapor in contact with the surface occurs, the superheated vapor no longer rushes away from the skin, in search of that vacuum, which is the accompaniment of a usually low dew point, but merely transfers its heat to the next particle of cold vapor, which is packed in convenient juxtaposition to receive it; or else an actual movement of the heated vapor effects a circulation or current which brings a new cold particle to receive a new increment of heat. In an atmosphere of this nature, the exhaled breath, and the exhaust steam from the workshops, evolve a cloud of apparent vapor, which must condense in cooling as the air absorbs its heat, for the saturation of the air forbids its absorption as an invisible gas. A Scotch mist of 36° (which is only a supersaturated air with vapor in excess at a slightly higher temperature than the air) penetrates clothing, and reaches every part of the person with distressing frigidity.

Passing upwards in the scale of temperatures from 50° to 65°, the point of equilibrium of cooling action by conduction or radiation of vapor in the air, with supply of heat from checked evaporation of the skin or lungs for attainment of comfort, seems to be reached. Perhaps the most healthful, or at least most stimulating, atmosphere for human breathing is found within these limits, when of natural and continued existence, so that within and without the doors the same

condition exists, and the regime of the bodily system is not disturbed from hour to hour. This, if not the ruling climatric condition of English life, at least is the presumed theoretic standard of English writers. Mental or physical exercise, alike, either separately or in conjunction, are supported by this condition of the atmosphere to an extent which no inhabitant of the frigid north, or enervating south, can imagine.

Some curious physiological phenomena accompany this atmospheric condition, one of which is the possibility of use of stimulants of the milder nature (wine and malt liquors), in quantities which would be immoderate in our climate. With the comparative cessation of cutaneous evaporation, it seems as if action of the alcoholic ingredient of the liquors were much changed and rendered more stimulating and less intoxicating.

From 65° to 80° a saturated atmosphere is sultry and oppressive. The surplussage of heat cannot be removed by conduction, and the natural effort of the system is to induce evaporation. The least physical effort produces, in the healthy person, abundant sensible perspiration, and the cooling effect of evaporation of a heated surface of water into a cooler air is the natural remedy. The lassitude and enervation of this step in the scale is eminently unfavorable to mental as well as to physical labor.

Above 80° a saturated air becomes burdensome; it is even questionable if life could be prolonged in a saturated air of 90° to 100°, and it is certain that at some point, not much above 100°, suffocation would ensue when any exertion should raise the animal heat above its normal degree. The deaths in the Black Hole of Calcutta were the result of excess of moisture, rather than of heat, or want of air *per se*. There are travelers' tales of regions on the Red Sea, and near the mouth of the Persian Gulf, where men cannot breathe in summer for the heat combined with moisture.

In the same way that the effect of a nearly saturated atmosphere has been examined, that of a very dry one may be investigated. To the sense of feeling all air may be said to be dry below 35°. The small amount of vapor present, and possible to exist as vapor below this point, reduces the conductivity so that the chilliness, to a great degree, disappears, even in a saturated air. Yet even here the cold producing effect of a high dew point is felt in a wind, so that from 15° to 35° the N. E. wind of our Eastern states is a very raw one. But,

on the other hand, with a dry air from 40° below zero to the freezing point, the immediate sensation of cold by the active man, well clad with porous clothing, is yet endurable, and with habit becomes almost pleasant. Still these temperatures are not those suited to civilized life, either physical or mental. As has been before noticed, we have in the Northern states about five months of the year, when the temperature ranges from 0° to 50°, and consequently when our civilized avocations demand artificial heating. The winter climate of the Eastern, Northern and Middle states, is one of great vicissitudes, with extremes, both of temperature and of hygrometric conditions following each other rapidly. In the Northwestern states, it seems that a somewhat greater uniformity of temperature, and a much more uniform hygrometry, exist during the winter months, but in the Middle Western states the irregularities appear to be as frequent as in the Eastern states. Except that the length of the winter season is a little cut short, and the excessive cold is a little alleviated in the southern portion of the belt of country I have designated, much the same phenomena of climate exist all through the states north of the 40th parallel of latitude. Throughout this territory it has become recognized that the minimum temperature of comfort for heated and ventilated rooms can be stated at 70°, with an admitted, and generally supposed inexplicable, if not unreasonable, demand, for 75° to 78° in some localities and at some times.

§ Ventilation means a supply of fresh air to the occupants of a house, workshop or meeting room of any kind; and as a final result, the quantity of such supply needed to attain the desired purity is from 40 to 60 cubic feet of air for each person each minute, where the contents of the rooms can be considered as furnishing a portion of the supply when occupancy is only for a part of the time. Much of the air may not be supplied through the heating apparatus. In cold weather, when the levity of the heated air within a building, compared with the colder air on the outside, produces a great pressure of outer air near the ground, the leakage of air at cracks of the door and window frames, at the top of the building, and its replacement by colder air through similar apertures at the bottom, furnish a much larger volume of air than is generally supposed. The strong winds also seek such leaks. Some permeability of walls, even of boards well painted, is available for the diffusion of vapor and of

gases in a measure. So that the proper quantity of air to be supplied by an apparatus, becomes a question to be considered, in each instance, on its own merits. But the fact still remains, that for each adult or child in health, 40 to 60 cubic feet of fresh air must be estimated as provided, either by arrangement or surreptitiously, for each minute they may occupy a room or place, although not necessarily during each minute of the day and night. This fresh air must be derived from out of doors.

Accept, for the sake of argument, the average temperature and dew point of Philadelphia, in January, February and March of 1844, as reported in Prof. Bache's meteorological and magnetic observations. The mean temperature of those three months was 34°, with an average dew point of 25°, barometer 30 inches from hourly observations, giving 68·8 per cent. of saturation. Using Guyot's Psychrometrical Tables, Regnault's data, 1·57 grains of aqueous vapor exist in a cubic foot of such air. These, in Philadelphia at this season, are the unquestioned properties of the air, from which is to be furnished the fresh air of ventilation. If heated to 70° without increment of moisture, the dew point remains unchanged, and the same 1·57 grains of moisture appertain to the enlarged volume of air, now increased 8·2 per cent. by expansion. The hygrometric condition of this air is but 1·44 grains per cubic foot, or but 18 per cent. of saturation. The summer hygrometric condition of air can be derived from the same source. The three months of July, August and September give 71° average temperature, with 60° dew point, or 68·3 per cent. of saturation. Suppose we take the 68·3 per cent., and consider it the proper condition for the air of ventilation at 70°; it then follows that 5·46 grains of moisture should accompany each cubic foot of air in winter. One more step in calculation, and I have done. A cubic foot of air at 70° weighs 0·074 lbs., and if it has been elevated in temperature from 34° or 36°, then 0·635 unit of heat will have been expended in warming the air. Again, if the amount of moisture present in this cubic foot of air has been increased from 1·44 grains to 5·46 grains = 4·02 grains, then 0·612 unit of heat will have been expended in evaporation of water to supply the moisture to vaporize the air. The quantity of heat for warming very nearly corresponds with the quantity of heat for vaporization!! The tension of vapor of the external air at 34°, with 25° dew point, is 0·155

inch of mercury; that at 70°, with 59° dew point, is 0·515 inch of mercury. It follows that the pressure tending to diffuse the aqueous vapor from the "hydrated" room to the external air, would be 0·365 inch of mercury. The vapor itself, within the room at the same time, possesses but one-forty-eighth the tension of that of the air present, and hence, as it is endeavoring to escape under the pressure of about 25 lbs. per square foot (which corresponds to the 0·365 inch of mercury column), it becomes evident that it would diffuse through cracks, outlets, and even through the passages for supply of fresh air, with great rapidity, and that this ratio of saturation is practically impossible to maintain in any *ventilated* room, or even in any room whatever, as ordinarily enclosed and built.

These estimates and considerations show fairly what would result from the attempt to produce an artificial summer climate in the houses of our Northern states in winter; but while the futility of the effort in its complete accomplishment is made evident by them, it by no means follows that some degree of hydration of warmed air is not the requisite of health or of comfort, and the question recurs, what proportionate hydration is needed for these ends?

[To be continued.]

ELEMENTARY SPECTRAL HARMONIES.—II.

By Pliny E. Chase, LL.D.

[Continued from Vol. lxxiv, p. 288.]

The interferences of harmonic undulations, which are supposed to be influential in planetary aggregation and elementary molecular grouping, should be most obvious in the spectral lines which are most prominent. Hence, we can hardly hope to find any more conclusive evidence of such interference than is presented by the figurate harmonies of alternate Fraunhofer lines, the subordinate harmonies of intermediate lines, and the exponential embodiment of the same fundamental series in the solar system.[1]

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[1] This Journal, Vol. lxxiv, p. 284

The multitude of faint and microscopic lines in the solar spectrum is so great that a variety of apparent harmonies might be readily found, of which many would be reasonably open to the suspicion of merely accidental coincidence, and it would be difficult to find any satisfactory criterion for distinguishing the true from the casual. We may, however, fairly presume that the elementary spectra offer a good field for preliminary investigation, and that such observations as give the least number of lines are especially worthy of early study. Such accordances as are found in groups which have been already measured, may become valuable guides in the formation of future groups, and means may, perhaps, be thus devised for co-ordinating the investigations of Clarke, Cooke, Gibbs, Hinrichs, Kopp, Mendelejeff, Wrede and Wurtz, and opening a new world for scientific exploration.

The wave-measurements, in all of the following comparisons, are taken from the paper of Professor Wolcott Gibbs, in the *American Journal of Science*, second series, vol. xlvii, pp. 198, *seq.* Kirchhoff's lines are indicated by K; Huggins's, by H; Gibbs's groupings of corresponding lines, in the observations of both Kirchhoff and Huggins, by K H; the left hand columns containing Kirchhoff's estimates, and the right hand columns those of Huggins:

MERCURY, K H.

Wave-Lengths.		Quotients.		Theoretical.	
568·47	568·55	1·0000		1·0000	1
546·33	546·13	1·0407	1·0411	1·0406	$1+6a$
542·80	542·80	1·0473	1·0484	1·0474	$1+7a$

LEAD, K H.

Wave-Lengths.		Quotients.		Theoretical.	
561·29	561·46	1·0000		1·0000	1
537·71	537·85	1·0439	1·0439	1·0440	$1+3a$
439·07	438·93	1·2784	1·2792	1·2784	$1+19a$

LITHIUM, H.

Wave-Lengths.	Quotients.	Theoretical.	
610·73	1·0000	1·0000	1
479·48	1·2277	1·2214	$1+2a$
459·93	1·3279	1·3321	$1+3a$

Ruthenium and Iridium, K.

Wave-Lengths.	Quotients.	Theoretical.	
635·45	1·0000	1·0000	1
545·44	1·1650	1·1646	$1+5a$
530·52	1·1973	1·1975	$1+6a$

Chromium, K.

Wave-Lengths.	Quotients.	Theoretical.	
541·35	1·0000	1·0000	1
521·20	1·0387	1·0387	$1+111a$
520·98	1·0391	1·0391	$1+112a$
520·83	1·0394	1·0394	$1+113a$

Copper, K.

Wave-Lengths.	Quotients.	Theoretical.	
578·67	1·0000	1·0000	1
529·30	1·0933	1·0914	$1+6a$
522·24	1·1070	1·1066	$1+7a$
465·64	1·2428	1·2437	$1+16a$

Arsenic, K H.

Wave-Lengths.		Quotients.		Theoretical.	
617 54	617·67	1·0000		1·0000	1
611·69	611·67	1·0096	1·0098	1·0093	$1+a$
578·95	578·73	1·0667	1·0673	1·0650	$1+7a$
533·55	533·41	1·1566	1·1580	1·1579	$1+17a$

Magnesium, K.

Wave-Lengths.	Quotients.	Theoretical.	
518·73	1·0000	1·0000	1
517·64	1·0021	1·0020	$1+2a$
517·17	1·0030	1·0030	$1+3a$
459·62	1·1286	1·1285	$1+9b$
448·57	1·1564	1·1570	$1+11b$
448·39	1·1569		

Tin, K H.

Wave-Lengths.		Quotients.		Theoretical.	
645·83	645·27	1·0000		1·0000	1
615·59		1·0491		1·0530	$1+a$
556·83		1·1598		1·1590	$1+3a$
556·59		1·1604		1·1620	$1+2b$
510·55	510·40	1·2650	1·2642	1·2650	$1+5a$
459·47		1·4056		1·4050	$1+5b$
453·41		1·4244		1·4240	$1+8a$

Potassium, H.

Wave-Lengths.	Quotients.	Theoretical.	
630·85	1·0000	1.0000	1
624·81	1·0097	1·0097	$1+\frac{1}{3}a$
613·25	1·0287	1·0291	$1+a$
583·78	1·0806	1·0802	$1+c$
581·79	1·0843	1·0843	$1+b$
580·80	1·0862	1·0872	$1+3a$
551·96	1·1430	1·1454	$1+5a$
483·18	1·3360	1·3371	$1+4b$
438·96	1·4372	1·4362	$1+15a$
431·16	1·4632	1·4653	$1+16a$
426·00	1·4809	1·4810	$1+6c$
418·77	1·5064	1·5057	$1+6b$

Silver, K H.

Wave-Lengths.		Quotients.		Theoretical.	
547·55	547·44	1·0000		1·0000	1
546·96	546·63	1·0011	1·0015	1·0013	$1+a$
521·32	521·34	1·0503	1·0501	1·0502	$1+38a$

This cannot be regarded as a satisfactory accordance.

Zinc, K H.

Wave-Lengths.		Quotients.		Theoretical.	
636·99	637·37	1·0000		1·0000	1
610·64	610·89	1·0432	1·0442	1·0390	$1+a$
589·90	589·90	1·0798	1·0805	1·0781	$1+2a$
472·25	471·98	1·3488	1·3504	1·3513	$1+9a$

Cadmium, K H.

Wave-Lengths.		Quotients.		Theoretical.	
647·22	647·08	1·0000		1·0000	1
644·59		1·0041		1·0041	$1+a\div 28$
531·27	531·01	1·2182	1·2186	1·2300	$1+2a$
509·00	508·83	1·2715	1·2717	1·2727	$1+5b$
480·56	480·27	1·3468	1·3473	1·3450	$1+3a$
468·10		1·3826		1·3818	$1+7b$
441·94	441·81	1·4645	1·4646	1·4600	$1+4a$

The quotient of Kirchhoff's sixth wave-length by the seventh (468·10 ÷ 441·94), is equal to the quotient of the fourth by the fifth (509 ÷

480·56 = 1·0592). The harmonic denominators, $1+7c$, $1+11c$, $1+15c$—if $c = 311{\cdot}6$—give 1·2181, 1·3428, 1·4674; but this is not so satisfactory a representation, on the whole, as the one I have adopted. $(2+3+4)a = (5+2\times7)b$.

LANTHANUM, K.

Wave-Lengths.	Quotients.	Theoretical.	
538·56	1·0000	1·0000	1
538·43	1·0003	1·0003	$1+\frac{1}{4}a$
538·00	1·0011	1·0011	$1+a$
534·48	1·0077	1·0077	$1+7a$
520·80	1·0341	1·0340	$1+31a$
519·20	1·0373	1·0373	$1+34a$
518·69	1·0383	1·0384	$1+35a$
481·59	1·1183	1·1183	$1+108a$

SODIUM, H.

Wave-Lengths.	Quotients.	Theoretical.	
616·74	1·0000	1·0000	1
616·56	1·0002		
590·04	1·0452	1·0455	$1+6a$ $(6=1+5)$
589·43	1·0462		
569·46	1·0830	1·0835	$1+11a$ $(11=1+2\times5)$
568·90	1·0840		
515·90	1·1954		
515·37	1·1966	1·1973	$1+26a$ $(26=1+5\times5)$
498·87	1·2362	1·2362	$1+31a$ $(31=1+6\times5)$

ANTIMONY, K H.

Wave-Lengths.		Quotients.		Theoretical.	
630·84	630·49	1·0000		1·0000	1
613·50	613·73	1·0283	1·0273	1·0270	$1+2a$
598·41	598·72	1·0542	1·0531	1·0540	$1+4a$
591·61	591·45	1·0663	1·0660		
589·76	589·76	1·0697	1·0691	1·0675	$1+5a$
564·54	564·41	1·1174	1·1171	1·1165	$1+3b$
557·19	557·18	1·1322	1·1316	1·1350	$1+10a$
546·61	546·33	1·1554	1·1540	1·1553	$1+4b$
471·10	471·03	1·3391	1·3385	1·3375	$1+25a$

Arsenic, K.

Wave-Lengths.	Quotients.	Theoretical.	
617·54	1·0000	1·0000	1
611·69	1·0096	1·0093	$1 + a$
603·38	1·0235	1·0244	$1 + 2b$
578·95	1·0666	1·0653	$1 + 7a$
558·29	1·1063	1·1096	$1 + 9b$
550·42	1·1219	1·1217	$1 + 10b$
538·75	1·1462	1·1461	$1 + 12b$
533·55	1·1574	1·1585	$1 + 17a$
521·32	1·1846	1·1826	$1 + 15b$

The sixth quotient is also very nearly $1{\cdot}1212 = 1 + 13a$; or $13a = 10b$.

Barium, K H.

Wave-Lengths.		Quotients.		Theoretical.	
650·24	650·44	1·0000		1·0000	1
611·75	612·15	1·0629	1 0625	1·0634	$1 + 4a$
603·08	602·70	1·0782	1·0792	1·0792	$1 + 5a$
597·05	597·58	1·0891	1·0885	1·0890	$1 + 15c$
585·51	585·67	1·1106	1·1106	1·1109	$1 + 7a$
582·88	582·77	1·1156	1·1161	1·1159	$1 + 2b$
578·51	578·00	1·1240	1·1253	1·1246	$1 + 21c$
553·95	554·06	1·1738	1·1740	1·1739	$1 + 3b$
552·40	552·06	1·1771	1·1782	1·1780	$1 + 30c$
493·78	493·57	1·3168	1·3178	1·3168	$1 + 20a$
490·20	490·23	1·3265	1·3268	1·3264	$1 + 55c$

The eighth quotient is also very nearly $1 + 11a = 1{\cdot}1742$; or $11a = 3b$.

Strontium, K H.

Wave-Lengths.		Quotients.		Theoretical.	
641·38	641·39	1·0000		1·0000	
553·90	553·74	1·1579	1·1583	1·1592	$1 + d$
552·57	552·38	1·1607	1·1614	1·1610	$1 + e$
550·83	550·61	1·1645	1·1649	1·1647	$1 + 3a$
549·11	549·78	1·1680	1·1666	1·1675	$1 + 3b$
548·68	548·75	1·1689	1·1686	1·1691	$1 + 3c$
525·98	525·95	1·2194	1·2195	1·2195	$1 + 4a$
524·18	524·26	1·2236	1·2234	1·2234	$1 + 4b$
523·24	523·23	1·2258	1·2258	1·2255	$1 + 4c$
522·97	522·83	1·2264	1·2268	1·2266	$1 + \rho d$
522·71	522·60	1·2270	1·2273	1·2272	$1 + \sqrt{2}e$

The ratio between the first and the ninth harmonic increment, $\rho = 1{\cdot}4232$, is my theoretical value for the ratio between heat of constant pressure and heat of constant volume;[1] the ratio between the second and the tenth harmonic increment, $\sqrt{2}$, is the ratio between dissociative- or wave-velocity, and stable- or circular-velocity. The geometric mean of 1·1645, 1·1680, 1·1689, is $1{\cdot}1671 = 1 + 3 \times 557{\cdot}16$; $(1{\cdot}2194 \times 1{\cdot}2236 \times 1{\cdot}2258)^{\frac{1}{3}} = 1{\cdot}2229 = 1 + 4 \times 557{\cdot}16$. Huggins's means are not so theoretically exact, but their deviation is far within the limits of probable error, for $(1{\cdot}1649 \times 1{\cdot}1666 \times 1{\cdot}1688)^{\frac{1}{3}} = 1{\cdot}1668$; $(1{\cdot}2195 \times 1{\cdot}2234 \times 1{\cdot}2258)^{\frac{1}{3}} = 1{\cdot}2229$; $1 + 3 \times 556{\cdot}8 = 1{\cdot}1670$; $1 + 4 \times 556{\cdot}8 = 1{\cdot}2227$. Kirchhoff gives the following additional lines:

(2) Strontium, K.

Wave-Lengths.	Quotients.	Theoretical.	
650·68	·9857		
554·52	1·1566		
461·69	1·3892	1·3893	$1 + 4\,a'$
461·62	1·3894	1·3898	$1 + 4\,b'$
431·38	1·4868	1·4867	$1 + 5\,a'$
431·18	1·4875	1·4872	$1 + 5\,b'$

Platinum, K H.

Wave-Lengths.	Quotients.	Theoretical.	
598·22 598·14	1·0000	1·0000	
596·86 596·59	1·0023 1·0026	1·0026	$1 + 3\,a$
595·62 595·47	1·0044 1·0045	1·0044	$1 + 5\,a$
548·07 547·95	1·0915 1·0916	1·0910	$1 + 5\,b$
530·70 530·76	1·1272 1·1270	1·1275	$1 + 7\,b$
523·10 523·08	1·1436 1·1435	1·1419	$1 + 7\,c$
506·43 506·32	1·1812 1·1813	1·1825	$1 + 9\,c$
456·19 454·92	1·3113 1·3148	1·3129	$1 + 20\,d$
450·77 449·72	1·3271 1·3300	1·3285	$1 + 21\,d$
445·65 444·45	1·3424 1·3455	1·3442	$1 + 22\,d$

This is not given among the comparisons in Gibbs's Table XI, but it embraces all the lines in which Huggins's measurements (Table IV) and Kirchhoff's (Table IX) differ by less than a unit. The groups may be connected by the equations, $21\,a = b$; $10\,b = 9\,c$; $6\,b = 7\,d$.

[1] *Proc. Soc. Phil. Amer.*, xiv, 651.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[1]

By Dr. A. Hofmann.

From the *Chemical News*.

[Continued from Vol. lxxiv, page 402.]

Compounds of Nitrogen.

Ammonia and Ammoniacal Salts.—By M. Seidel, Director of a Manufactory in Amsterdam.—Although in the report of the London Exhibition of 1862 it was justly asserted that the ammonia manufacture was still in the same condition as in 1851, there has been, during the last ten years, an essential alteration, and this branch of industry has been developed in an unexpected manner, both technically and commercially.

Up to 1860, the manufacture of ammoniacal salts was trifling in proportion to the existing supply of the raw material. The price of the products was too low to stimulate an increased production, and the technical manipulations were generally of a very primitive character.

Latterly, and especially since 1870, the use of the sulphate of ammonia for agricultural purposes has increased year by year, and both the technical and the commercial evolution of the manufacture have kept pace with the growing demand.

Among the ammoniacal salts met with in commerce, the sulphate has a quite preponderating importance, and is used almost exclusively in agriculture or in the manufacture of alum.

The use of caustic ammonia has also greatly increased, but, on the other hand, the consumption of sal-ammoniac, both sublimed and crystallized, has greatly fallen off, so that in many establishments the plant for this branch has been removed, and replaced by apparatus for the production of the sulphate of ammonia.

The sources of ammonia have remained essentially the same.

The first rank is still occupied by the so-called ammoniacal liquor or gas-water from the gas-works, in comparison with which all the other raw materials may be said completely to vanish.

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[1] "Berichte über die Entwickelung der Chemischen Industrie während des letzten Jahrzehends."

The quantity of ammoniacal salts obtained from the by-products of the prussiate of potash works, from the manufacture of animal charcoal, and from putrid urine, etc., form but a very small fraction of the total production.

Proposals for opening up new sources of ammonia have certainly not been wanting. Thus Hunt[i] patented, in England, a process for obtaining sal-ammoniac by passing a mixture of hydrochloric acid and nitrogen (or air) over ignited coke, previously saturated with ferric or manganous chloride. This is merely the resuscitation of a proposal made eighteen years ago by R. Wagner,[ii] the only difference being that Hunt uses salts of manganese, whilst Wagner recommends a salt of magnesia. The process has not hitherto obtained industrial importance. The same may be said concerning Hutchinson's[iii] process, which consists in distilling the nitrogenous residues of the starch manufacture in retorts, along with lime or caustic soda. Brief mention must also be made of the method of Coste and Paupin de Rosnay,[iv] for utilizing the ammonia of canal water.[v] The water is to be mixed with magnesia and a soluble phosphate, the precipitate of ammoniaco-phosphate of magnesia is to be collected, dried, and ignited with lime in retorts. The ammonia given off is conducted into an acid, whilst the residue is utilized as manure. In this case also the matter has not gone beyond the experimental stage.

Preparation of Ammonia from Gas-Liquor.—The ammoniacal liquor, which collects partly in the condensers and partly in the washing apparatus of gas-works, consists of a mixture of volatile and fixed salts of ammonia in very variable proportions. Among the former are ammonium sulphide and carbonate and free ammonia, whilst the latter consist mainly of the ammonium salts of sulphocyanogen and hyposulphurous acid, along with traces of the sulphate and chloride. The total percentage of ammoniacal compounds

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[i] Hunt, *Chem. News*, 1864, ix, 62.

[ii] R. Wagner, *Wagner's Jahresberichte*, 1856, 83; 1857, 122.

[iii] Hutchinson, *Chem. News*, 1864, ix, 31.

[iv] Coste et Paupin de Rosnay, *Ann. d. Génie Civil*, 1867, 807; *Monit. Scientifique*, 1868, 516; *Deutsche Industrie Zeitung*, 1868, 298.

[v] The water in question is probably that of Dutch canals which receive the sewage of the streets through which they pass. The same process has been patented in England for the treatment of sewage.—Ed. *C. N.*

fluctuates greatly, but as it is to the advantage of the gas works to absorb the ammonia as far as practicable, and as concentration of the gas-liquor increases its values, it is now generally delivered stronger than was formerly the case.

The approximate valuation of the ammoniacal liquor is effected by means of a hydrometer, but as the specific gravity of the liquor is essentially affected both by the quality of the water originally used and by the presence of foreign constituents, the hydrometric valuation is very uncertain, as will appear from the following table, in which samples of gas-liquor of equal value, according to the hydrometer, but different in strength according to analysis, are grouped together.

Degrees Beaumé at 15° C.

2°	2·50°	3°	3·50°	4°	4·50°	5°	6°
1·16	1·30						
1·42	1·43						
1·50	1·63	1·63					
1·77	1·77	1·76	1·87				
	1·98	1·90	2·00				
	2·18	2·10	2·24				
	2·65	2·38	2·40	2·55			
		2·45	2·72	2·72	2·79		
				2·90	2·85		
				3·40	3·06		
					3·40		
					3·53	3·67	3·74

The percentage of fixed ammonia is, on the average, 0·3, whether the hydrometer indicates a higher or a lower degree. The percentage of sulphur ranges from 0·33 to 0·50.

The utilization of the liquor is generally effected by expelling the gas by distillation in iron boilers, which are heated either by direct fire or by steam, air being simultaneously forced in [J. Braby[1] and J. Baggs]. Certain English manufacturers make use of apparatus resembling the scrubbers at gas-works in which the gas-liquor flows down from above, whilst the steam, at a high tension, rises up from below—a process objectionable in so far that such establishments can

[1] J. Braby, *Chem. News*, xx, 182.

either not use lime at all, or must employ it under unfavorable circumstances.[1]

In the establishment of Messrs. Van der Elst & Matthes, of Amsterdam, the ammoniacal liquors from most of the Dutch gas-works are treated for sulphate of ammonia as follows, having been brought by water in barges specially constructed:

The liquor is distilled in iron stills, holding from 35 to 50 hectolitres each, and heated by steam, which is furnished by five steam boilers of 30 horse-power each. The stills are fixed at the same level, and are grouped in pairs, which can be worked alternately, being connected by reciprocating cocks.

The volatile constituents are first distilled off without the addition of lime, and then the quantity of milk of lime required for the decomposition of the fixed ammoniacal salts is driven in by steam pressure. The products of distillation pass first into a collecting vessel, and from here through 5-inch (13-centimetre) valve-cocks into large receivers filled with sulphuric acid, in which the ammonia is absorbed without the slightest loss, since the cocks are so arranged that the products may be conducted at will into one or the other receiver.

The residual watery vapor, plentifully contaminated with sulphureted hydrogen and carbonic acid, is removed from the receivers by a special chimney fitted with an arrangement for burning the sulphureted hydrogen.

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[1] The following description of the apparatus used in the manufacture of caustic ammonia at the works of Messrs. Jaffé & Darmstädter, of Berlin, has been communicated to the editor by Dr. L. Darmstädter. It consists of three superposed boilers, containing about 50 hectolitres, the two lower being heated by direct fire, and provided with agitators, to ensure a perfect commixture of the lime and the gas-liquor, and to prevent the lime from burning to the bottom of the boiler. The upper boiler serves as a preparatory heater, and, to a certain extent, as a dephlegmator. The gas from the third boiler is passed, for the removal of watery vapor, through an arrangement of Liebig's condensers as extended as possible, and, preferably, 20 to 25 metres in length, from which it finally escapes into the washing bottles and condensing apparatus, which are connected together by means of a tube filled with wood charcoal, for the absorption of any residual empyreumatic matter. By a sufficient length of the pipes, and by the interposition of more washing bottles, it is possible to obtain chemically-pure ammonia. In the manufacture of caustic ammonia, it is of course essential to introduce into the still, before the commencement of the operation, the whole of the lime needful for decomposition, as otherwise the resulting product may be easily contaminated by volatile ammoniacal compounds, such as ammonium sulphide and carbonate.

The escaping vapor, on its way to the chimney, traverses prolonged series of pipes, which raise the temperature of the gas-liquor about to be distilled to 50° or 60°. Besides an important economy in fuel, this arrangement produces the further advantage, that the gaseous mixture deposits a great part of its watery vapor, which greatly facilitates the combustion of the sulphureted hydrogen.

The annual production at the works of Van der Elst & Matthes amounts to about 1200 tons sulphate of ammonia.

All establishments where gas-liquor is treated in quantity, are compelled to pay great attention to the pernicious emanations which are inseparably connected with this manufacture.

Unless proper precautions are taken, not alone the residents in the neighborhood suffer from the copious development of sulphureted hydrogen, but the men employed in the works are attacked with violent inflammation of the eyes.

The progress made in this direction consists, principally, in the improvement of the burners for the combustion of the noxious gas, and the construction of chimneys with increased draft.

The Compagnie Parisienne d'éclairage et de chauffage par le gaz, which, in its three large establishments, produces yearly about 3000 tons sulphate of ammonia, and, in addition, large quantities of caustic ammonia, has described, in a special treatise,[1] the arrangements adopted for the sanitary improvement of its works.

As another important improvement, must be mentioned the safety-valves which are now attached to every still. Although, under ordinary circumstances, these apparatuses work at a very low pressure, obstructions may nevertheless be produced, in the gas delivery-tubes, under a variety of circumstances, and may easily occasion explosions, such as took place, in 1867, at the establishments of Van der Elst & Matthes, of Amsterdam, and of Kunheim & Co., of Berlin. These dangers are, once for all, obviated by the introduction of safety-valves.

Ammonia and Ammoniacal Salts.

By M. SEIDEL, Director of a Manufactory in Amsterdam.

Applications of Ammonia.—As already mentioned, the consumption of sulphate of ammonia in agriculture has become more and more established. In comparison with guano, and with all putrescent

[1] Note relative aux divers produits et aux ouvrages exposés à Vienne par la Compagnie Parisienne.

manurial matters, this salt has the great advantage that all its ammonia is combined, and, although in consequence of this fact the effect is less rapid than that of guano, it is decidedly more permanent.[i]

The production of caustic ammonia likewise has manifestly increased. Large quantities are required by Carré's ice-machine, which, although still encumbered with a variety of defects, is daily finding a more extended application.[ii]

Caustic ammonia is also more and more required in the tinctorial arts, and very recently it has unexpectedly come into use in the preparation of indigo in Java.

According to the old process for the preparation of the color from various species of *Indigofera*, lime was added to the fermenting mass. A Belgian chemist, J. Sayers, of Djocjocarta, in Java, has introduced there a new process. Instead of lime he adds ammonia during the fermentation, and is said in this manner to obtain a purer color.

The successful resumption of the method tried more than thirty years ago to produce soda by treating chloride of sodium with carbonate of ammonia, has also lately given a considerable impulse to the manufacture of ammonia. Should, as it almost appears, the ammonia-soda process come into use on a larger scale this circumstance would very essentially contribute to a further development of ammonia manufacture.[iii]

The condensibility of ammonia and its great solubility in water, have inspired the idea of using it as a motive power for machinery.

The earliest experiments in this direction are due to Tellier and Flandrin.[iv] In connection with these attempts Tellier has subsequently

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[i] Recently repeated attempts have been made to extract by direct lixiviation, the ammonia which accumulates in the composition employed in gas-works for purifying purposes (bog-iron ore and saw-dust) and to utilize it as manure. In consequence, however, of the abundant presence of sulphocyanide in the sulphate, and of its pernicious action upon vegetation, these experiments have led to no favorable result.—Private communication, of Dr. L. Darmstädter to the editor.)

[ii] Compare the paper by Dr. Meidinger in an earlier portion of this report.

[iii] According to private communications which the editor has received from German manufacturers, an increase of the demand for carbonate of ammonia, in consequence of its application to the ammonia-soda process, is as yet scarcely perceptible.—(A. W. H.)

[iv] Tellier and Flandrin, *Comptes Rendus*, lx, 59; *Monit. Scientifique*, 1865, 134; *Dingl. Pol. Journ.*, clxxvi, 163; *Deutsch. Industrie Zeitung*, 1865, 126; *Wagner Jahresber.*, 1865, 279.

sought to make ammonia useful in a variety of technological applications, but without arriving at any decided success, which may be partially due to the circumstance that the commercial value of ammonia has so greatly increased of late years. Tellier has collected his suggestions and published them in a separate work—"L'Ammoniaque dans l'Industrie." Paris: J. Rothschild, 1867. Delaporte[i] also has patented an ammonia machine in France.[ii]

We may, in conclusion, briefly mention a few proposals respecting the preparation of various ammoniacal compounds.

As is well known, ammonia is fixed not only by acids, but by many salts, which, in this case, play the part of an acid. These compounds, which have been experimentally examined by H. Rose, Persoz, and Rammelsberg, give off the ammonia when heated, a property which is often used in the laboratory for the preparation of liquefied ammonia. Latterly Knab[iii] has proposed to obtain such saline compounds of ammonia industrially, and to store up the gas in this form. Such compounds would then only require a gentle heat in order to evolve a current of dry ammoniacal gas. Chloride of calcium can in this manner take up 50 per cent. of its weight of ammonia, whilst strong liquid ammonia contains only 20 per cent. of dry ammonia. This latter assertion is an error, since water, even at 15°, is capable of taking up more than 30 per cent. of its weight of ammoniacal gas.

Ammonium sulphide, so frequently employed for analytical purposes, has been hitherto almost exclusively prepared by passing sulphureted hydrogen into caustic ammonia. It is now obtained by Spence[iv] industrially by mixing ammonium sulphate or chloride with twice its weight of alkali-waste or gas-lime, exposing the mixture to the action of steam, and condensing the products of distillation in suitable apparatus.

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[i] Delaporte, *Génie Indust.*, August, 1865, 63.

[ii] Lamm, of New Orleans, is said (*Engineer*, Jan., 1875) to have constructed an ammonia-machine, which has been successfully tried for street tramways; the chief difficulty, the loss of ammonia, is almost overcome by the use of an oil joint in the stuffing boxes.

[iii] Knab, *Chem. News*, 1866, xiii, 192; *Deutsche Industrie Zeitung*, 1866, 178; *Wagner Jahresber.*, 1866, 205.

[iv] Spence, *Mech. Mag.*, Nov., 1866, 307; *Dingl. Pol. Journ.*, clxxxiii, 397; *Polyt. Centralb.*, 1867, 461.

Kunheim[i] has introduced a simple, but under certain circumstances very advantageous, improvement in the manufacture of ammonium carbonate. Previously this salt had been almost exclusively prepared by the double decomposition of sal-ammoniac and carbonate of lime, the chloride of calcium, relatively worthless, being obtained as by-product. Kunheim employs, instead of carbonate of lime, the carbonate of baryta, and obtains a solution of baric chloride, which may be advantageously used in the preparation of permanent white.

Nitric Acid and its Salts.

By Dr. Adolph Geyger, of Berlin.

Even at the commencement of the present century, a part of the saltpetre consumed in the various countries of Europe came from India as so-called exotic saltpetre,[ii] and the rest of the supply was obtained as native saltpetre by the lixiviation of natural or artificial nitre beds.

The consumption of nitrates in the chemical arts, and in the manufacture of gunpowder, and of other blasting materials, has increased to such an extent that the earlier sources became utterly insufficient. A new supply was laid open in the vast deposit of a mineral very rich in nitrate of soda, discovered more than fifty years ago in the district of Tampa, on the border between Chili and Peru.[iii] The extraction of this deposit is still on the increase, and furnishes by far the largest part of the raw material for the nitrates now used in the arts.

According to the statements of Dr. G. Langbein[iv] there were in the year 1871 in the Peruvian nitre districts, eleven large refineries with a daily production of about 6000 cwts. purified nitrate of soda. The nitriferous mineral, called *caliche*, is found in beds from 0·25 to 1·5 metres in thickness, which, however, rarely rise to the surface. The superincumbent rock, *costra*, is from ½ to 2 metres in thickness, and consists principally of a hard conglomerate of sand, feldspar, phosphates, and other minerals. The composition of the *caliche* fluctu-

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i Kunheim, *Deutsche Indust. Zeit.*, 1866, 178; *Chem. News*, 1866, xiii, 192; *Wagner Jahresber.*, 1866, 202.

ii The terms exotic and native saltpetre are not known in the English trade.—Ed. *C. N.*

iii Rivero, *Schweigger's Journ.*, xxxiv, 450.

iv Langbein, *Wagner's Jahresber.*, 1871, 300, and 1872, 290.

ates; it contains 48 to 75 per cent. nitrate of soda, 20 to 40 per cent. chloride of sodium, and varying quantities of sulphates of soda and lime, nitrate and iodate of potassa, chloride of magnesium, etc., as also insoluble earthy matters and organic substances (guano). It is first broken up in a disintegrator and placed in the dissolving pans. Some of the establishments use long four-sided cisterns, but the better arranged works use closed egg-shaped boilers provided with two movable covers, of which the upper serves for the introduction of the *caliche*, and the lower for the removal of the exhausted material. The mass rests upon a perforated false floor, fixed at about one-fourth the height of the boiler, and consisting of four pieces, movable on hinges. The boilers are filled up to the top with the broken raw material, and up to half height with mother-liquor, and are heated by the direct action of steam, which is admitted by four pipes reaching below the false bottom. In from one and a quarter to two and a half hours the liquid is sufficiently saturated with nitre and is let off into settling tanks; after some hours' rest the clear liquor flows into flat crystallizers, fixed in an open place and exposed to the wind. Latterly a second settling-tank has been interpolated, in which the liquid is allowed to remain for about half an hour, in order to deposit the common salt which is held in mechanical suspension before being run into the crystallizers.

The residue left in the boilers, which still contains from 15 to 35 per cent. soda saltpetre, is either cleared out at once or extracted once more with spring water. The closed boilers are simply emptied by letting down the lower or true bottom, when the residue falls into wagons run in beneath, and is drawn away from the works. The crystals of nitre which form in the crystallizing pans after the mother-liquor is drained away, are spread upon a large surface exposed to the wind, and called *cencha*, in layers of from 30 to 50 centimetres in thickness, and dried by being frequently turned over. The total cost of 1 cwt. of Chilian saltpetre up to its conveyance to Europe was calculated in the year 1871 by Langbein, as follows:—

Cost of production, ...	3·25 marks
Conveyance to the coast, . . .	2·40 "
Cost of shipping, ...	0·25 "
Freight to Europe, ...	2·75 "
Charges on arrival, ...	0·25 "
	8·90 "

or about 8*s.* 8*d.*

W. Lloyd,[1] in 1868, calculated the cost of production at 8·40 marks per cwt. The rise of price in spite of the improvements in the process of purification, is due to the enormous increase in the cost of labor and in the freight to the Port Iquique. Although the saltpetre districts have been now for some years connected with the port by a railway, the greatest part of the produce is still conveyed upon mules.

The exportation of nitre is still constantly on the increase, as the following figures prove:—

1830,	18,700	cwts.
1835,	140,399	"
1840,	227,362	"
1850,	511,845	"
1860,	1,370,248	"
1870,	2,943,413	"
1871,	3,605,906	"
1872,	Upwards of 4 million	"

By the decree of July 12th, 1873, the Peruvian Government has taken the saltpetre trade into its own hands, and has fixed the quantity that may be yearly exported at 4½ million cwts. As to the effect of this monopoly upon the saltpetre trade, no decision can as yet be formed.

As a specimen of the composition of the purified soda saltpetre, as imported into Europe, the following very complete analysis, published by Wagner,[11] may be cited:—

Sodium nitrate,	94·03
" nitrite,	0·31
" chloride,	1·52
" sulphate,	0·92
" iodate,	0·29
Potassium chloride,	0·64
Magnesium chloride,	0·93
Boracic acid,	trace
Moisture,	1·36
	100·00

The mother-liquor of the refineries contains from 2½ to 5 grms. iodine per litre, and is used in some Peruvian establishments as a source of that body. (Compare chapter on Chlorine, Bromine, and Iodine.)

[1] Lloyd, *Wagner's Jahresber.*, 1869, 247.

[11] R. Wagner, *Wagner's Jahresber.*, 1869, 248.

As to the origin of these saltpetre beds in Peru, various explorers have published their opinions, but without giving a fully satisfactory explanation. Indeed it would almost seem as if the formation had taken place under circumstances which have remained hitherto unknown. According to H. Reck,[i] Chili saltpetre is the oxidation product of large guano beds, whereby, however, as Nöllner very justly remarks, it remains unexplained what can have come of the great mass of sparingly soluble phosphate of lime, whilst the readily soluble nitrate of soda remains behind.[ii]

The hypothesis of C. Nöllner[iii] possesses the greatest amount of probability. He believes that in consequence of storms, prodigious masses of seaweed, all nitrogenous, have been driven into that bay of South America, and have given rise to nitrate of soda by a process of slow oxidation.

In support of his view Nöllner adduces the constant occurrence of iodine in the nitrates, and concludes, therefore, that their origin can be due only to seaweeds, those nitrogenous collectors of oceanic iodine. The geographical position of the saltpetre beds agrees, in fact, very well with this theory, since on this coast west winds blowing from the sea predominate, their action being supported by the currents flowing along the coast. If these westerly winds only a few times in the course of centuries became violent hurricanes, and threw colossal masses of seaweeds collected from the enormous surface of the Pacific upon the land, which is entirely rainless, and consists of a parched-up plain or a hilly alluvium, a zone of seaweeds would be formed exactly as represented by the nitre-beds of Peru. We should, of course, have to assume that the nitre when formed was withdrawn from the action of the waves by volcanic elevation or by the retrocession of the sea. The small percentage of potassium in Chilian nitre corresponds with the proportion of potash in the seaweeds, and the constant occurrence of boro-sodio-calcite reminds us of the boriferous minerals in rock-salt and in deposits of potassium chloride.

[To be continued.]

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[i] H. Reck, *Berg- u Hütten-Zeit.*, 1863, 188, 207, 225, 229; Wagner, *Wagner's Jahresber.*, 1863, 303.

[ii] Without wishing to advocate the guano theory, we may point out that the *costra*, or superincumbent rock, has just been described as consisting in part of phosphates. —Ed. *Chem. News.*

[iii] C. Nöllner, *Journ. Prakt. Chemie*, cii, 459; *Wagner Jahresber.*, 1868, 290.

NOTE ON THE THEORETICAL EXPLANATION OF FRAUNHOFER'S LINES.

By Henry Hartshorne.

Professor Henry Draper, in his recent paper upon the "Discovery of Oxygen in the Sun by Photography," etc., indicates his conclusion that the theory of the constitution of the solar spectrum must be modified, in view of the facts presented in his investigations. This conclusion is obviously true, so far, at least, as regards the demonstration of the existence of oxygen, and the great probability of that of several other substances not hitherto therein recognized, in the sun. But some other modification of the accepted theory of the spectrum, it appears to the writer, is also demanded by the same and by some other now known facts.

Professor Draper suggests that "the reason of the non-appearance of a dark line may be that the intensity of the light from a great thickness of ignited oxygen overpowers the effect of the photosphere." He adds that "such an explanation would necessitate the hypothesis that ignited gases, such as oxygen, give forth a relatively large proportion of the solar light."

This is a hypothesis of so considerable violence, in view of familiar facts, that there is room to examine whether another explanation may not be arrived at, which will include all the facts, some of which Professor Draper's observations seem to have brought into contradiction. Of course, the opposition cannot be in the facts themselves, but must be in our views of them. The apparent contradiction referred to is thus alluded to by Professor Draper: "At first sight it seems rather difficult to believe that an ignited gas in the solar envelope should not be indicated by dark lines in the solar spectrum, and should appear not to act under the law 'a gas when ignited absorbs rays of the same refrangibility as those it emits.'" Then follows this important remark: "the substances hitherto investigated in the sun are really metallic vapors, Hydrogen probably coming under that rule. The non-metals obviously may behave differently." It is then added, "it is easy to speculate on the causes of such behavior." In the way of speculation thus indicated, the only suggestion

made is that above quoted, regarding the possibly great thickness of ignited oxygen overpowering the effect of the photosphere. Another view of the facts now under remark appears to the writer more consistent with the whole history of the solar spectrum; although not less opposed to the commonly accepted mode of statement, according to which the dark lines are accounted for by an ignited gas "*absorbing* rays of the same refrangibility as those it emits."

In a paper read before the American Philosophical Society, April 21st, 1876,[1] after a description and proposed explanation of some facts concerning ocular spectra, I remarked of those facts, that "they have a definite relation to the mode of production of the Fraunhofer lines or 'absorption bands' of the spectroscope." Further thought upon the same and other phenomena induces me to believe that a definite relation of the kind indicated may now be referred to, as, along with Professor Draper's observations, giving ground for proposing a totally different view of the causation of Fraunhofer's lines from that which has been hitherto universally accepted.

It will hardly be necessary to remind the readers of this JOURNAL of the nature of the ordinary explanation, by "absorption," beyond the account of it contained in the words cited above from Professor Draper's article. Since Kirchhoff's announcement of this explanation, in 1859, it has been practically undisputed. Professor Stokes very early proposed to illustrate it by the analogy of the "absorption" of sonorous vibrations. Tyndall describes this illustration as follows: "A stretched string responds to aerial vibrations which synchronize with its own. A great number of such strings stretched in space would roughly represent a medium; and if the note common to them all were sounded at a distance, they would absorb the vibrations corresponding to that note. That is to say, *they would absorb the vibrations which they can emit.*"

While sensible of the boldness of such a demurrer, I must submit that this illustration is not exactly *applicable* to the case of Fraunhofer's lines. The same may be said of another version of the proposed analogy, which has been given by Professor Lommel, of Erlangen.[2] The latter reads as follows: "If a large number of tuning

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[1] "On Some Disputed Points in Physiological Optics," *Proceedings of Am. Philosophical Society*, 1876.

[2] "On The Nature of Light," etc.; 1876, p. 252.

forks be imagined to be attached to a table, and a sound wave unisonal with them be excited at one end, it will reach the other in a very weakened condition, because its energy will have been in great measure absorbed by the tuning forks. A wave of another pitch will, on the contrary, traverse the layer of tuning forks almost unaltered, and will spread beyond them without noticeable loss."[1]

Prof. Lommel adds that the undulatory theory thus affords an explanation of absorption, inasmuch as it shows that "every body must absorb exactly those kinds of luminous rays which it is itself capable of emitting."

This last statement, taken by itself, is undoubtedly true; and, in regard to sound, especially, it has been admirably illustrated by Tyndall and others, by many experiments. But, there are two *conceivable* kinds, or cases of so-called absorption. One is that of the above experiments, with *silent* stretched strings, or *silent* tuning forks, which are *made to vibrate* in resonance with the vibration of a string, or a fork, when that is struck so as to elicit its tone, with which that of the others corresponds. The *other* case, strictly analogous to that of the Fraunhofer line-phenomena which need to be explained, should be that of undulations emanating from a vibrating string, or tuning fork, which undulations, impinging upon other consonant strings or forks *already in vibration*, will be thereby *weakened* and *annulled*.

Supposing this result really to follow in such an experiment, it would still bear another mode of description and explanation. But, for brevity, I will at once approach the positive view which appears to me preferable in regard to Fraunhofer's lines.

Obviously, it is altogether correct to say, with Prof. Lommel and others, that "ignited vapors are *opaque* for rays of their own kind, while perfectly permeable to all other kinds of rays." If Kirchhoff's discovery and explanation of the meaning of the dark lines of the solar spectrum had gone no farther than this, it would have been, as it is, a magnificent contribution to science, on account of its immediate and various applications in chemistry and astronomy. Without access to Kirchhoff's original papers (Berlin Academy, 1859), I am unable to ascertain whether his expressions did or did not include the

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1 The use of the word "*imagined*" in this account by Prof. Lommel, suggests the query: Has *precisely this* experiment ever been actually *tried*?

idea of "absorption" as conveyed in the citations above made from Stokes, Tyndall and Lommel.

But the view which I wish to propose may be distinctly expressed, by substituting for *absorption* the word *interference*. Since my paper, above mentioned, was printed, I have met with a retrospective account, by Prof. J. W. Draper,[1] of his early observations upon the spectrum. In this retrospect, Prof. Draper mentions that, in photographing the solar spectrum to fix the Fraunhofer lines, he "allowed *daylight to fall along with* the sun rays on the photographic surface. The *daylight and the sunlight antagonized each other*," and thus "ultra-spectrum heat lines," beyond the red, appeared as positive photographs. He mentions, also, that Foucault and Fizeau, in 1846, reported the existence of the same "ultra-spectrum" lines, and stated their observation (as Draper says) of "*the antagonizing action* above described." Another experimenter, about the same time, failed to obtain these heat lines beyond the red, on account of his *exclusion of diffused daylight* from the photographic surface.

With so eminent an authority employing expressions such as have just been cited from Prof. J. W. Draper, it cannot be called presumption, nor even novelty, to speak of *interference*, in connection with the phenomena of the spectrum. Not feeling competent to deal with the more abstruse theoretical questions at once raised by the demand for the reconciliation of this "case" (if it be such) of interference, with the classical instances rendered so familiar by Huyghens, Young, Fresnel and others, I must content myself with one or two further suggestions here.

Experiments to exhibit the interference of vibrations, either of sound or light, are as yet, considering the importance of the inquiry, not very numerous. The subject is one but incompletely studied. As Lommel states, the reason why interference by *direct opposition* of equal rays is not demonstrable, is that we cannot secure sufficient accuracy in the equivalence of opposition. Irregularities will occur. But, while light-waves travel through space at the rate of 186,000 miles per second, it is inconceivable that *interference by direct and diffusive opposition* should not at times occur. In the case of a luminous burning solid, surrounded by its own glowing vapor, the

[1] *Harper's Magazine*, April, 1877, p. 898, *et seq.*

simplest view is that the undulations emanating from the luminous centre are met, opposed and partially annulled by the *antagonizing action* of the equivalent vibrations of the glowing vapor particles. Here especially we may notice, with Prof. Henry Draper, that "all the substances hitherto investigated in the sun are really metallic vapors, hydrogen probably coming under that rule." At least, then, in the case of all but hydrogen, it is conceivable that *luminous particles*, capable of *returning interfering* vibrations in the paths of those emanating from the central sun-mass, exist in the photosphere. It does not need that all, or nearly all, of the sun's emanating vibrations, in any one path, should be thus neutralized by interference. On this point, we need only to remember that the "dark" lines are only *relatively, not absolutely, dark.* Prof. J. W. Draper observed, long ago (*Phil. Magazine*, 1843), and many others have noticed since, that there is a great difference, at different times and under various circumstances, in the *relative visibility* of the Fraunhofer lines.

In regard to hydrogen, it may be observed that the special character of its molecular constitution and susceptibility of movement, shown by chemical relations to ally it to metallic substances, may be readily believed to affect it like them in its relations to the vibrations of light; even although our acquaintance with it does not favor the supposition of its containing, like the metallic vapors, particles capable of becoming visibly luminous to us.

It would seem, then, not too much to say, that, with the re-opening by Prof. H. Draper's discovery and some other new facts, of the question as to the *theory of the spectrum*, the subject of interference needs to be further investigated; and, particularly, what may be called *crass* interference, or that of the direct opposition of luminous waves, or rays, in *diffused* light.

As bearing incidentally upon this general topic of interference, I may now mention some facts quite recently observed. If before anywhere reported, they have, I think, not yet found their place in current treatises. They may be designated as phenomena of *cross lights.*

1. In a square room, let diffused daylight be admitted from windows on two sides, say the north and west, so as to fall upon a sheet of white paper about equally distant from the two windows. Two shadows of an object, such as the hand held over the paper, will then be

thrown upon the paper; one will be *rose or pink-red*, and the other *bluish-green*. In my observations, the shadow made by the north light is bluish or greenish, and that by the west light, orange or reddish. Other instances, however, of crossed-daylight shadows occur, where the two shadows thrown are, respectively, blue and orange.[i]

2. When a student's kerosene lamp is burning in a room, just before sunset, so that the lamplight and that of a window will make two shadows of an object, one of these shadows (that thrown by the window light) will be orange, and the other (thrown by the lamp) blue.

3. Let the light of a full moon and that of a student's lamp so fall in a room upon a white surface, that they will throw upon it shadows of about equal intensity, in nearly opposite, or at least different, directions. One of these shadows, of a hand, for instance, or of a stick, will be reddish-orange, viz., that thrown by the moonlight; the other, thrown by the lamplight, greenish-blue.

Whatever difficulties of application may appear, in theory, concerning "half-wave lengths," "opposing phases of undulation," etc., in endeavoring to explain these and many other phenomena, of complementary shadow-tints, spectra, etc.,[ii] no other term appears to me to be appropriate to them but *interference*. It may be, and no doubt is, very often, in such cases, only a partial arrest of light-waves that occurs, with relative obscuration, or color change. Especially in the case of the Fraunhofer lines, as contrasted with such definitely measurable examples as those of the "colors of thin plates," there may be some advantage in the distinction attempted to be conveyed by the expression, *crass* interference.[iii]

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[i] In all these cases, the colors of the shadows are not intense, or they would have been very often noticed. They are, however, quite clearly distinguishable, by persons having ordinary normal sight. A certain *proportion* of the cross lights is, of course, necessary; I have seen the complementary shadows, in the daytime, only with *diffused* daylight; not under the direct rays of the sun.

[ii] See my paper above referred to, in *Proceedings of Am. Philosophical Society*, April 21, 1876.

[iii] The word *crass* is from the Latin, through the German; meaning nearly, though not precisely, the same as *gross*.

APPARATUS FOR PRODUCING ELECTRIC LIGHT.

By GUSTAVE TROUVÉ, M.E.

The attention which I have given to the subject of lighting by dynamo-electric machines, has for its end the securing of much greater efficiency to all machines.

Electro-magnets, in their operation, deviating but little from the law of gravitation, I have thought that their action should be effected under similar conditions. I have, therefore, been led to working always by contact, in order to obtain the greatest possible efficiency.

In ordinary machines,[1] the effects are commonly produced at a great distance; hence there results a great loss, as, for example, in the Gramme machine. Some work under better conditions, the electro-magnets acting in closer proximity. Nevertheless, the distance necessary for the play of the parts always occasions a loss, which may be estimated in the ratio of about 1 to 8, if there is contact, a loss which would be much less if the magnetic circuit was complete, as well as the electric circuit.

The principle which I have patented, and which is applicable with remarkable generality, aims at combining these two conditions of maximum, consequently augmenting the effect in a notable degree.

I will briefly describe a machine, arranged for acting in accordance with my principle:

The machine is composed of two or more electro-magnets in permanent magnetic contact, and participating in a rotary movement, like the trains of a rolling mill. The magnetic and electric circuits are, therefore, closed, which can be said of no other machine.

This arrangement fulfils the two conditions of maximum above named. The magnetic contact being constant, the machine never needs priming. Small machines, built on this plan, operate as well as large machines. This has been, hitherto, impossible, because they did not retain enough residuary magnetism.

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[1] We may except the Laade machine, in which the Siemens bobbin acts in magnetic contact. But it has a slipping friction so rapid, that it is transformed into heat, rendering continuous action almost impossible. In my machine, on the contrary, all the frictions are rolling.

In the accompanying sketch I have represented only the parts essential for the successful application of my principle, purposely omitting the important, but well-known, accessories.

The application of the principle requiring the play of all the parts, the entrance and exit of the currents is made through the axles, which are hollow, and admit in the centre the insulated conductors, of which the extremities are seen at t, t', t'', t''', t'''', t''''', t''''''.

Figs. 1 and 1′ represent front and side views of a machine, composed of a strong, straight electro-magnet, influencing a series of straight electro-magnets, and forming a circular bundle. The whole system

Fig. 1.

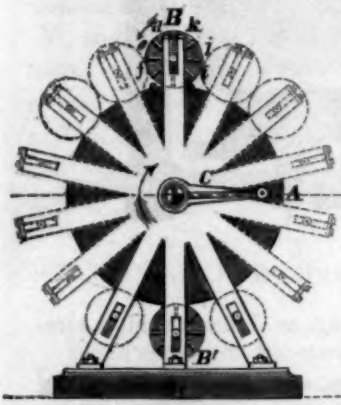
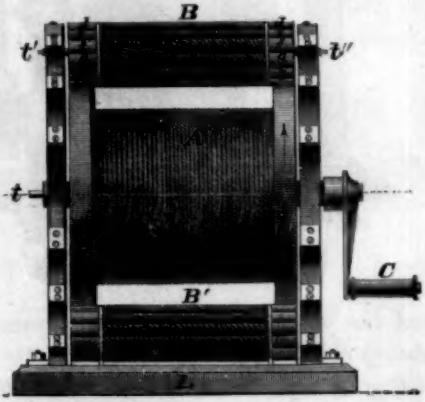


Fig. 1′.



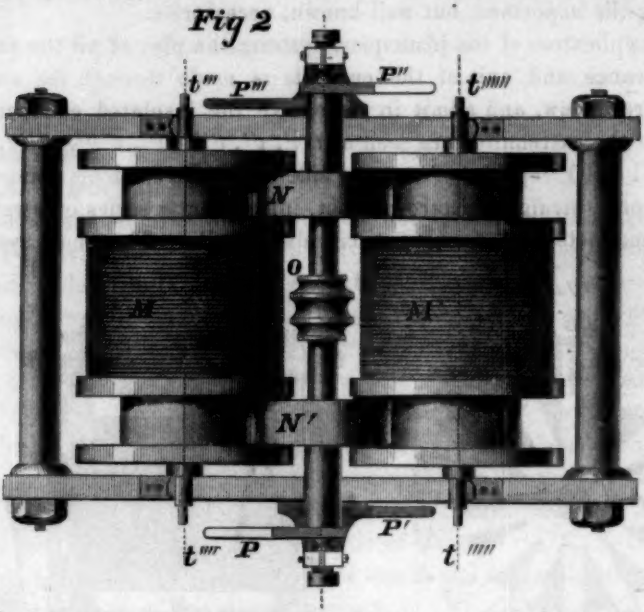
is set in rotary motion by the great electro-magnet, which also serves as a regulator. The machine can give either reciprocating or continuous currents, like the Gramme machine, according to the arrangement of the commutator. It is either magneto- or dynamo-electric, according as an electro-magnet or a permanent magnet is employed.

If the motion is such as indicated by the arrow, all the electro-magnets, d, e, f, g, placed at the left of the perpendicular, passing by the centre or axis, approach the great electro-magnet, which affects them, and generates, in their respective bobbins, positive currents; all the electro-magnets on the right of the perpendicular, h, i, j, k, receding from the great electro-magnet, are influenced by negative currents. A special commutator collects these currents, either to use them in quantity or in derivation, or to give them in tension.

Fig. 2 represents a Gramme machine, arranged on this principle. It is evident that the two electro-magnets, M, M', are in permanent

contact, by their opposite poles, with the two discs *N*, *N'*, thus forming a single magnet, for which one of the discs serves as a shank,

Fig 2



and the other as an armature, constituting, as I have said, a completely closed magnetic circuit.

Fig. 3 represents, in section, one of the two discs, *N*, *N'*, which are mounted on the common axle, *O*. When they are set in motion they communicate a rotary movement to the two electro-magnets, which influence them continually, and thus generate currents in the series of bobbins which form the discs. The contact becomes more complete, between *M*, *M'*, and *N*, *N'*, in proportion as the currents are stronger; in other words, as the speed of the machine increases.

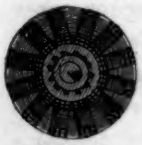


Fig. 3

Reference.

Figs. 1 and 1'. *A*, large electro-magnet, serving as fly-wheel, moved by the crank, *C*, or by a pulley mounted on its axle.

B, *B'*, cluster formed of the small electro-magnets, *d*, *e*, *f*, *g*, *h*, *i*, *j*, *k*.

C, crank.

L, support.

Fig. 2. *N, N'*, modified Gramme discs, moving the two electro-magnets, *M, M'*, which influence them.

O, pulleys to set the axle in motion.

P, P', P'', P''', friction springs, collecting the currents which are generated in the discs.

t, t', t'', etc., extremities of the coils of the electro-magnets.

Fig. 3. Section, in the plane of motion, of the modified Gramme disc.

This machine can easily yield, for each of its discs, a light equivalent to 600 carcel burners, in every way suitable for demonstrating the principle. The two electro-magnets, *M, M'*, can be separated at pleasure from magnetic contact with the two discs, *N, N'*, and the diminished intensity of the current will be immediately seen.

RELATIVE COST OF WATER- AND STEAM-POWER.

By Henry P. M. Birkinbine.

When erroneous statements are put into print, it is almost impossible to correct them. An evidence of this is presented in an assertion contained in the article, under the above head, in the Journal for December, page 388: "The cost of raising water by water-power at the Fairmount Works in Philadelphia is but *two cents per one million gallons*, raised one foot high."

In an article published in the Journal for May, 1876, page 323, the commercial value of Fairmount water-power is presented, and figures given, taken from the reports of the Water Department, which show that, as compared with steam, the water pumped by the water-power works was, at a cost of from $13,000 to $19,500 per annum, above what it would have cost to have done the work by steam, with pumping engines of the same average efficiency as those in the works.

The two cents referred to, as the cost of raising one million gallons, one foot, by water-power, were expended for simply running the works, that is, attendants, oil, tallow, and ordinary repairs; it does

not represent the entire cost of operating the works; it leaves out of consideration the extraordinary repairs, incident to water-powers, those of maintaining the dam, head-race, gates, etc.

The water-power at Fairmount has cost the city of Philadelphia between one, and one and a quarter millions of dollars, for water-rights, damages, dam, head-race, mill-houses, wheels, and pumps. The precise cost is difficult to ascertain, as many of the expenditures were made in connection with other work. Taking the interest of one million dollars ($60,000), as the annual cost of the power, and dividing it by the water pumped in 1876, 8,374,657,743 gallons lifted into the reservoirs, it will show that the power alone cost over eight cents per million gallons, lifted one foot. To this must be added the running expense, two cents, and also the cost of extraordinary repairs, incident upon maintaining the dam, head-race, etc. It is therefore evident that the cost of raising water at Fairmount by water-power, is between ten and twelve cents per million gallons, one foot.

The water-power on the Schuylkill, next above Fairmount, at Manayunk, owned by the Schuylkill Navigation Company, and leased to eighteen different manufacturing establishments, has a power equal to one thousand horses; and for this power the company receives a yearly rental of $43,100, or $43.10 per horse power, per annum. Even at this low figure, it is a question which is the cheapest, water or steam, when the annoyance of low water, floods, and interferences of the navigation are taken into account. Were this power now unoccupied, the yearly rental would not warrant its utilization, simply for a water-power.

Since the steam engine has been brought to the degree of perfection, in simplicity, efficiency, economy, and reliability, that we now have it, there are few locations in the thickly settled portions of our country, where fuel can be procured at a moderate price, that water-power will be found cheaper or more desirable than steam-power. This is particularly the case where the water-power is unfavorably located, and where the trouble, incident to drought, floods, etc., is taken into account. There are unimproved water-powers in this vicinity, and many which have been improved are now unemployed and allowed to go to decay.

Philadelphia, December 13*th*, 1877.

ON THE EMPLOYMENT OF ZINC IN BOILERS AS A PREVENTIVE OF FRESH WATER SCALE.

By Brossard de Corbigny, Mining Engineer.

[Translated from the *Annales des Mines*, of 1877, for the Journal of the Franklin Institute, by Chief Engineer Isherwood, U. S. Navy.]

Mr. Lesueur, formerly an employee of the telegraphic companies, has presented to the Minister of Public Works, and also to the Academy of Sciences, a memoir relative to the employment of zinc in steam boilers as a scale preventive. The author, in that document, relates the circumstances which led him to an examination of this question. During the repairs of a steamer at Havre, in 1861, after several years' service, it was observed with surprise, that, while one of her boilers, fed with sea-water direct from the sea, was almost wholly oxidized and useless, the other two, fed with water from the condenser, were in perfect preservation, and that some brass partitions in the condenser were reduced to the state of pure spongy copper, the zinc of the alloy having entirely disappeared. From these facts arose the supposition that zinc could be employed as a scale preventive; and since 1873, Mr. Lesueur has been engaged in bringing it into common use, or at least in having it tried by a great number of manufacturers at Angers, and in the department of Maine-et-Loire. Under these circumstances, the Minister of Public Works ordered us on the 16th of October, 1876, to closely observe these trials, ascertain the value of the process, discover the cause of the action of the zinc, and find out the best method of applying it.

We will here state that a great number of recommendations had been furnished by manufacturers who had tried the use of zinc, and that, independently of those given in the memoir, others were sent to us; the owners of the boilers which we examined also confirmed the favorable results, with very rare exceptions, whose cause we have still to find. We limit ourselves to the mere mentioning of these things, and shall hereafter deal only with what we have ourselves discovered.

We will investigate successively:

1. The material facts attending the use of zinc.
2. Their explanation.

3. The influence of the nature of the water used in the boilers.
4. The precautions to be taken in practice.

1. The Mode of Action of Zinc.—The application of the process consists in simply placing a quantity of zinc in any part of the boiler farthest removed from the furnace; whether the zinc shall be in large or small masses, must be determined by the circumstances of each particular case. The boiler being then filled, is continued in operation during the ordinary time, and when cleaned, if the kind of water used produces calcareous deposits, the following will be observed:

When the water is but little calcareous, the deposits, instead of forming solid and adherent scale, remain in the state of fluid-mud, easily removable by simple washing. The iron being clean and not rusted, no picking or scraping is needed, which effects a great economy of time, hand-labor and oversight.

When, however, the water is strongly calcareous, the deposits are as coherent and stony as though the zinc had not been employed; but what is extremely important, this scale, while acquiring its thickness and hardness, does not adhere to the iron. It can be pulled off by hand, or, at the worst, detached without much effort, leaving the iron clean. A simple washing removes it from the boiler, and in this case, as in the previous, picking and scraping are avoided.

As regards the zinc itself, it is not strictly correct to say it has disappeared; but it has been transformed, *in situ*, into its oxide, a white and earthy substance, which often preserves the lamellar texture of the metal, the central part sometimes continuing metallic and unattacked. Evidently there has been a slow oxidation, and time has occasionally been wanting for a complete metamorphosis of the zinc into oxide of zinc. A specimen taken from the Desert Mine boilers (Maine-et-Loire), fed with water from the river Loire, gave, on analysis, the following composition:

Water,	1·60
Oxide of Zinc,	87·30
Oxides of Iron and Aluminum,	3·80
Sand and Clay,	1·60
Carbonate of Lime,	6·20
Carbonate of Magnesia,	0·50
	101·00

On the other hand, no trace of dissolved zinc was found in the water taken from the boilers; and but very feeble quantities were found in the scale deposited from this water. To determine this last fact, we have analyzed the solid and abundant scale formed in the boilers of the Raynaly works of Angers. These boilers were fed from a well, near the river Maine; and their scale had the following composition:

Carbonate of Lime, ...	75·60
Carbonate of Magnesia, ...	3·00
Sulphate of Lime, ...	9·35
Sand and Clay, ...	8·40
Oxides of Iron and Zinc, ...	4·20
Chlorides, ...	0·40
	100·95

It is indubitable that the oxide of zinc was dragged by the water currents, and thus mechanically mixed with the scale. Two kinds of deposit are, therefore, formed under these circumstances, and they must be distinguished from each other: the one derived from the feed-water, and precipitated in the usual manner of scale upon the water-heating surfaces, but without adhering to them; the other formed almost wholly of the oxide of zinc, and remaining entirely, or nearly so, where the metal was placed. The water taken from the boiler when it was cleaned, contained, after filtration, no trace of metal. Some specimens of water taken from the boilers of the Raynaly and the Laboulais works at Angers, and from those of the Desert and Legal Mines at Nantes, having been treated with the sulphohydrate of ammonia, gave no appearance of coloration or reaction.

The results are very different when the boilers are fed with selenious water, instead of the calcareous water used in the foregoing cases. We have established the following at the slate works of Angers, and with three boilers (La Paperie, les Petits-Carreaux, and l'Hermitage).

The feed-water, generally drawn from old abandoned excavations, is extremely hard, and its deposits consist essentially of the sulphate of lime, colored by a little oxide of iron. The presence of this salt in water traversing only schistose formations is explained by the fact that the slaty schist contains numerous crystals of iron pyrites, transforming, under the influence of air and moisture, into sulphate of iron, which reacts in its turn upon the lime contained, in small

proportion, in the schist, and in some calcareous veins running through it, forming sulphate of lime holding only traces of iron; these traces are so feeble that the water is not colored by the sulphohydrate of ammonia, but the oxide of that iron, being concentrated in the deposits, colors them a light pink.

When the water is used without a scale preventive, the sulphate of lime is deposited in the form of mud, of which only a part adheres to the iron, forming a thin crust of scale having the following composition by analysis:

Sulphate of Lime, ...	88·00
Sulphate of Iron, ...	2·70
Ferruginous Clay and Sand, . . .	4·50
Water, ...	4·60
	99·80

The abundance of the gypsum-mud compels such frequent cleaning of the boilers (every month or six weeks) that the scale has not time to acquire much thickness.

The addition of zinc has not given any valuable result; at the most, the scale has been observed to be a little less thick with its concave surface flat and glossy, in place of being undulating; but its adhesion to the iron was strong, requiring picking and scraping to remove it; so that after over a year of fruitless efforts, the employment of zinc has been discontinued. Perhaps not enough metal was used, but if this kind of water, highly charged with scale-producing salts, requires too large a quantity, there would be no economic advantage in the use of zinc.

2. Theoretical Explanation.—The preceding data enable us to frame a theory of the phenomena. Mr. Lesueur, in his memoir, explains them as electrical effects, of which, however, he does not clearly define the action, and which, at the first glance, do not appear to be justified; nevertheless, we believe his explanation is correct, and sufficient to account for the phenomena observed.

We must begin with the fact that the zinc, not being dissolved, and consequently not being brought into contact with the boiler surfaces, does not act as a coating or as an emulsion which mechanically prevents the adherence of the scale. The zinc undergoes oxidation, and

can obtain its oxygen only from the air dissolved in the feed-water, or from the oxygen constituent of that water: the first hypothesis leads to no satisfactory explanation; the second, on the contrary, involves the following: The two metals, iron and zinc, surrounded by water at a high temperature, form a voltaic pile with a single liquid, which slowly decomposes the water. The liberated oxygen combines with the most oxidizable metal—the zinc—and its hydrogen equivalent is disengaged at the surface of the iron. There is thus generated over the whole extent of the iron influenced, a very feeble but continuous current of hydrogen, and the bubbles of this gas isolate at each instant the metallic surface from the scale-forming substance. If there is but little of the latter, it is penetrated by these bubbles, and reduced to mud; if there is more, coherent scale is produced, which, being kept off by the intervening stratum of hydrogen, takes the form of the iron surface, without adhering to it.

Experience has shown that for about three months' use of a boiler, during twelve hours per day, one pound of zinc should be employed for each five square feet of water-heating surface. The pound of zinc requires 24·628 pounds of oxygen for its saturation, and this oxygen is combined in the water with 3·0785 pounds of hydrogen, occupying in the gaseous form, at the temperature of 32° Fahr., and under the standard atmospheric pressure, 550·5 cubic feet, which, in the boiler, is reduced in the direct ratio of the boiler pressure, making the bulk of hydrogen, for a pressure of five atmospheres, say 110 cubic feet. This is the volume of hydrogen which would be employed during about three months, or, say, 1100 hours' use, to maintain a thin gaseous stratum, interposed between five square feet of iron and the scale. The quantity, though certainly small, we believe sufficiently large to justify our explanation. The presence of this small quantity of hydrogen could never be a source of danger to the boiler, though doubtless it would form, in proper proportions, an explosible mixture.

But how explain why the same effect was not produced with the selenious water of the slate works of Angers? Should it be attributed to the more coherent nature of pure sulphate of lime, or to an insufficient quantity of zinc employed? We cannot, at present, pronounce with certainty on that point, and limit ourselves to simply reporting the facts established by observation.

The hypothesis we have framed is, furthermore, confirmed by the following fact mentioned in the memoir of Mr. Lesueur, but which we have not had an opportunity to verify: Zinc introduced into a boiler whose surfaces had been imperfectly freed of scale, has the property of detaching the remainder. This effect is well explained by the action of a feeble disengagement of gas beneath the scale, raising it little by little, and separating it from the iron.

3. Influence of the kind of Feed-Water used.—The foregoing already gives an idea of this influence, which we make more precise by the following remarks:

A. Soft Water Type. *Boilers of the Desert Mines fed with water from the river Loire.*—This water, when treated with nitrate of silver, gives a light precipitate of chloride of barium, and nitrate of ammonia; not anything when treated with lime-water; it marks 8½ hydrometric degrees.

The employment of one and a half pounds of zinc per ten square feet of water heating surface, permits a boiler to be used during three or four months without forming scale; the deposit has no adhesion, and can be removed by simply washing out the boiler.

Boilers of the Laboulais Works at Angers, fed with water from the river Maine.—The effect of treatment with nitrate of silver was a little more marked, and a slight action was produced by lime-water; hydrometric degrees, 16. The employment of one pound of zinc for each ten square feet of water heating surface, permits a boiler to be used for several months. The deposit does not cohere, and can be removed by simply washing out the boiler.

Boilers of the Engines pumping water for the city of Angers, at the bridge of Cé.—These boilers are fed with the same water, and produce the same results as in the case of those of the Desert Mines.

B. Calcareous Water Type.—*Boiler at the Raynaly Works, at Angers, fed with water from the river Maine.*—This water comes from the Maine through about 330 feet of debris of demolished buildings, and gave abundant precipitates by the ordinary reagents; hydrometric degrees, 40. The scale was essentially calcareous, and in some places three-fourths of an inch thick, but it was not adherent to the iron, from which it came off easily. Chippings of zinc had been employed in the small proportion of two-thirds of a pound for every ten feet of water heating surface.

Boiler of the Legal Works at the City of Nantes.—This boiler was fed with water similar to the immediately preceding, but of only 27 hydrometric degrees. We have not seen these works, which are beyond our district, but we know, by a letter from the proprietor, that he is well satisfied with the results obtained in a tubular boiler of twelve horse-power.

C. Selenious Water Type. *Boilers of the Slate Works at the City of Angers.*—The feed-water of these boilers, when treated with the nitrate of silver, gave abundant precipitates of chloride of barium and of oxalate of ammonia, but none when treated with lime water. It was essentially selenious and non-calcareous, as explained by its origin, and marked from 40 to 45 hydrometric degrees. It formed a very hard scale of sulphate of lime. No sensible effect was produced by the employment of zinc in moderate quantities, and no trials were made with large quantities.

We have not been able to investigate two other types of water, which do not occur in our district, namely, sea water and acid water. The first would require special observations, and with the second no good result could be attained. In fact, the zinc would be rapidly dissolved in a solution of free acid strong enough to corrode the iron—as we have witnessed on other occasions—and at the end of a few days it would have disappeared, if employed in only sufficient quantity to saturate the feed-water, a consumption incompatible with an economic use.

Neither the type nor the form of the boilers appears to have any influence on the results. Our observations were principally made on plain cylindrical boilers, but several proprietors of tubular boilers have testified to the good effects obtained in them.

4. Manner of Employing the Zinc, and Precautions to be taken.—Our observations show that it is certainly better to employ the zinc in pigs or cubical masses, than in chippings or sheets. In the second case the electro-chemical action, being exerted over too large a surface, becomes too rapidly exhausted, while with cubical masses it is better graduated, and the metal more economically used.

The zinc can be placed on any part of the boiler, except the surfaces exposed to the radiant heat of the furnace; on them its pasty oxide causes burning and blistering, of which we have seen examples.

The end of the boiler most remote from the furnace appears to be the best place to put the metal.

The quantity of zinc to be employed depends obviously on the hardness of the water, on its rate of vaporization, and on the intervals between renewal. In circumstances where the process gives good results, one pound for every five square feet of water-heating surface should be considered the maximum; the one-half pound stated by the author of the memoir, is only sufficient for very soft water, or for very short periods.

It is scarcely necessary to remark that the employment of zinc cannot diminish the quantity of deposit from any given feed-water. We should not have mentioned this, had not some proprietors of boilers seemed to think they had effected the more or less disappearance of these deposits, although they could only have caused the diminution of their cohesion and adhesion to the surfaces. Others (Heilmann at Mulhouse, and the owners of the Desert Mine) apprehend that the valves and cocks of the boilers will be worn by the pulverulent scale, swept along by the steam currents, which evil could doubtless be remedied by means of a steam-drum of sufficient capacity.

CONCLUSIONS.

The following are the practical conclusions of the present report:

1. The process discovered by M. Lesueur, appears to be of incontestible value with calcareous feed-water, when not too hard; that is to say, when of not more than 25 or 30 hydrometric degrees. The deposits in this case lose all cohesion, or, at least, do not adhere to the iron, the cleaning of which, by picking and scraping, is thus avoided.

2. With selenious feed-water of 40 hydrometric degrees or more, the result is insignificant.

3. No better result would be attained with feed-water containing free acid.

4. The zinc should be employed by preference in cubical masses, and in quantities of from half a pound to a pound for each five square feet of water-heating surface during several months. It should be placed at the end of the boiler the farthest from the furnace, and the boiler should be furnished with a steam-drum of sufficient capacity.

IMPROVEMENT OF THE SOUTH PASS OF THE MISSISSIPPI.[1]

By E. L. CORTHELL, Resident Engineer.

In regard to the depth of channel that exists at present through the jetties, it will be sufficient to state that on the first day of November, this year, the steamship City of Bristol, of the New York and Liverpool Inman Line, passed through the jetties without detention and without touching. Her draught was 21 feet and 8 inches, the tide at the time was 2½ inches below "average flood tide," which is the plane of reference established by the United States Engineers.

It may not be generally understood that the delay in obtaining the deeper channels, demanded by the contract between Capt. Eads and the United States Government, has been caused mainly by the difficulties which have been met with in deepening the river shoal at the head of the Passes.

First, there was not a full knowledge and comprehension of all the conditions existing, nor of their relation to each other, and to the channel, which it was necessary to make into South Pass; secondly, it was necessary that the works should be partly tentative in their nature, and this fact demanded considerable time in which to observe their effects; thirdly, many months were consumed in building these extensive works which would control the whole volume of the river. All these causes have delayed the formation of the channels through the bar at the Gulf, where the jetties are located. Without entering, beyond a few explanations, into the discussion of this most difficult and interesting problem of river hydraulics, on which a treatise could well be written, we simply refer to the fact of its existence and of its intimate relation to the channel through the jetties.

There are conditions existing of so subtle a nature, with relations so obscure, and yet so entirely dependent upon each other; there are hidden causes, that operate so quietly and easily, to change existing conditions and destroy the equilibrium of natural forces; there are at times such unlooked-for results from the works constructed, and there are so many occult principles and unknown laws in the flow of water moving in immense volumes that are elucidated by these results, that, in the end, one of the most useful and interesting histories may be

[1] *Providence Journal.*

written, that will record in detail all the steps which have been taken to persuade the water of the great river to go where man directs.

With all the interest that may attach to the subject in the mind of a disinterested person, who views it all calmly from a distance, yet by those who have not only their reputations, but their financial prospects, at stake in the success of these jetties, it is deeply regretted that the completion of the work and the securing of the maximum channel have been delayed so seriously, and the success of the enterprise endangered by what appears now to have been false economy, which decided upon the improvement of the South Pass rather than of the Southwest Pass.

To improve, by the force of river currents, a shoal which lies as a great middle ground between the two main outlets of the river, is one of the most difficult of undertakings. To induce the river to leave the channels in which it has flowed for ages, and to seek a new and untried one, is in opposition to its conservative nature; it hesitates long, and is very loth to leave the old ways for the new.

It is necessary to show this almost sentient monster that there are sound hydraulic reasons for changing its ancient habits.

All the works that are built in the funnel-shaped mouth of South Pass, have a tendency to throw a part of its volume into the two large passes, which stand right there with their great, hungry mouths to take every drop that comes within their reach.

To avoid this result of our works, it has become necessary to hold the sections of these passes *in statu quo*, by laying on their beds a sill of willow mattresses, from our works, at the head of South Pass, to the east and west banks of the river.

The total length of these sills is about one mile and a quarter. They are simply the foundations of more extensive works of the same kind, by which we expect to control, slowly but surely, the whole river volume, and draw from it, what South Pass needs to obtain and maintain, a channel, 30 feet deep and 350 feet wide, to the deep waters of the Gulf of Mexico.

Another subject which we wish to refer to, especially, is the "re-formation" of the bar in front of the jetties; that "re-formation" that has been held up by some of our friends, as the great, final and grand obstacle to our success.

In the earlier stages of the work, it was the impossibility of securing even a twenty foot channel that troubled them; the absurdity

of our expecting any such result was so clearly patent to their minds that they thought their argument unanswerable, and convinced themselves at any rate of our prospective failure; but the 20 foot channel came, then the 21, now nearly the 22, and through the jetties a broad, deep channel, from 24 feet to 95 feet deep, has made its appearance, and has thus steadily and surely furnished us facts for our arguments that 30 feet would surely come.

Of late we hear but little of the absurdity of our intention to obtain a deep channel; but now it is *that bar*, that *new* bar, that is to form so rapidly, close up the jetty outlet, and bring disaster upon the whole enterprise!

Well, it is now two years and a half since we laid the first willow mattress on the South Pass bar. The same enormous volume of mud and water has flowed out through the jetties that formerly spread out like an open fan a mile and a half in width, and in addition to it nearly four million cubic yards of sand and clay have been excavated from the shoal at the head of the Pass and from the channel between the jetties and thrown out into the gulf.

The arguments on either side have facts now, or the absence of them, to prove or disprove the conflicting theories. The time has come when the American people who are to pay for this great work can demand the facts, that they may know whether all the money expended and to be expended, is irretrievably lost in a mud bank that will pay no dividend to its depositors, or will result in a deep and permanent outlet for the Mississippi Valley.

In the limited space allowed us in your crowded columns, we cannot give all the details connected with the facts in our possession. If we could do so, and could illustrate them by maps or diagrams, we could show to the satisfaction of the most obstinent opponent of the jetties that the re-formation of the bar, as prophesied, is a myth. We will briefly allude to the facts and give general results only.

In May, 1875, the United States Coast Survey, under the direction of Mr. H. L. Marindin, one of the most efficient and careful assistants in the department, made an accurate and detailed survey of the South Pass bar. This survey extended into the Gulf about half a mile from the outer crest of the bar.

In October of this year (1877), we made a survey, covering the same ground. The lines of soundings were run in the same manner

as those of Marindin. The general and detailed plan was similar to his. The work was plotted on the same scale. His soundings were increased by one foot and eight-tenths, to bring his plane of reference up to ours.

The whole area in front of the jetties was then divided into squares of one hundred feet. We took it for granted that between any two soundings of his, and also of ours, the slope was uniform. Depths were thus obtained for each corner of each square.

A skeleton was made, on which these squares were drawn; the calculated depth at each intersection was put down in one color for Marindin's survey, and in another color for ours, and we then had the data carefully arranged for calculations by the prismoidal formula. This plan was adopted on account of the unequal spacing of the soundings, and, while it is open to the charge of interpolation, it gives, under the circumstances, the most accurate results.

The depths having thus been put down, the skeleton was subdivided into larger areas and figures. Using the one thousand feet, between the present end of the jetties, as the base of a rectangle, the jetty lines were produced into the Gulf 2500 feet.

This figure was divided again into smaller rectangles of 1000 feet by 500 feet.

The large rectangle was enlarged by adding 1000 feet to the width at the outer end (500 feet on each side), but retaining nearly the same width at the end of the jetties. Then a larger figure still was drawn in the same way, and so on, until the final figure embraced the fan-shaped area of the discharge of sedimentary matter issuing from the jetties during high river.

The calculations show that over the rectangle (1000 feet by 500 feet), lying immediately in front of the jetties and adjacent to their ends, there has been an average deepening of four feet and two inches.

This is the identical ground over which the bar re-formation was to take place so rapidly. The rectangle first spoken of, namely, 1000 feet by 2500 feet, we will call A; the next larger figure B, the next C, and so on, each one embracing all the preceding. The result of these calculations is given in the following table.

A map exhibiting graphically the changes that have taken place, shows clearly that there are well defined areas of scour entirely across the whole mile and a half investigated, and at right angles to the end of the jetties.

We do not need to go beyond this map to prove the existence of a well marked and almost constant littoral or shore current of salt water, sweeping under the fresh water, and not only carrying to one side the vast amount of sediment thrown out of the jetties, but even digging down and cutting into and carrying off much of the original outer slope of the bar.

Letter of Combination.	Area of Combination, in square feet.	Mean gain in depth of Combination, since May, 1875, in feet.	Quantity of material scoured in Combination, since May, 1875, in cubic yds.
A, ...	2,500,000	0·878	81,341
B, ...	4,000,000	0·727	107,690
C, ...	5,300,000	0·996	195,609
D, ...	6,520,000	1·144	276,328
E, ...	7,770,000	1·166	335,572

The surveys and calculations made recently by Capt. M. R. Brown, U. S. Engineers, who is detailed by the Secretary of War to inspect the jetties for the Government, corroborated the statements we have made.

In his report of July, 1877, to the Secretary of War, he compares his survey of June, 1876, with that of June, 1877.

We quote some passages that refer to this special subject, and which are found on pages 26, 27 and 28:

"On sheet No. 4 will be found the results of a survey, in June 20th, to June 22d 1877, of a mile or more beyond the ends of the jetties, and for a considerable space on either side."

"The subject of fill and scour beyond the ends of the jetties has occupied so much attention that I have carefully compared the results of the survey of June, 1876, with that of June, 1877, and for the purpose have divided the whole area, comparable by means of the two charts, into twenty-one divisions."

"The fan-shaped areas are, of course, those of the most pressing interest when investigating the influences of changes in the immediate future of commerce."

"Taking into account all the divisions except 1, 7, 13 and 21, we find that the scour in the year was 1,145,976 cubic yards, equivalent to a scour of $1\frac{3109}{10000}$ feet, or 1 foot 3·7 inches over this latter area."

A Drainage Tunnel 31½ Miles Long.—The difficulty and expense of dealing with the drainage water of the mines in the district of Freiburg, Saxony, led to the abandonment of some of the most important of them nearly a century ago, and it became evident that other mines in the same district must soon suffer from the same cause; thus threatening an industry which had been prosecuted through several centuries.

A deep adit, or drainage tunnel, was the only hope for relief, and in 1838, O. von Huber proposed and published a plan of an adit, to start from the Elbe, near Massen, and follow a straight course to Halsbrücke, 22,000 metres distant. The cost to this point, where it would drain the abandoned government mine, was to be borne by the State; but beyond this the adit was to be extended to other mines at the expense of those to be benefited.

This plan was abandoned as too costly, and requiring too great a length of time to execute, and, in 1844, the Government commenced the construction of an adit from Rothschonberg on the Elbe, about 12 kilometres above Massen, the distance to Halsbrücke being much less. The latter plan originally contemplated an adit 12,882 metres long (exclusive of 334 metres of auxiliary drain and branches), 3 metres high and the same width; and at a depth of 89 metres less than the one first proposed, but 94 metres below the deepest adit then existing, and to have seven air-shafts. The estimated cost was $950,000 gold, and the time required, twenty-two years.

A change of plan, however, increased the length of the main adit to 13,900 metres, and necessitated an eighth air-shaft, which, with unforeseen difficulties in the execution of the work, greatly increased the cost, and prolonged the time for its completion to the beginning of this year—thirty-three years from its commencement.

The length of the main adit and its branches, now completed, is 43,000 metres; but further extensions are to be made, and when finally completed the total length will be 50,900 metres, or 31·6 English miles. The cost, up to the first of January, 1876, was 2,235,897 thalers, $1,609,845.84 gold.

All but a small portion of the adit is driven through solid gneiss rock, and up to October, 1875, all the work was done by hand; since then, however, rock drills, driven by compressed air, have been introduced with great advantage, both as to progress and cost.—*Engineering and Mining Journal*, of October 27th, 1877.

Experiments upon Homogeneous Iron.—From late experiments in the dockyard of Castellamare, the following inferences are drawn: 1. That punching alters the molecular constitution of homogeneous iron. 2. That this alteration does not extend more than a millimetre from the hole. 3. That annealing is of no use if it is employed before punching, but it restores the ductility if it is employed afterwards. 4. That this advantage is lost if the holes are subsequently enlarged by a reamer. 5. That drilled holes produce no sensible alteration in the molecular structure and ductility, even if they are slightly enlarged by a reamer. Experiments are contemplated with small punches, with a diameter at least 2 mm. smaller than the holes, the holes to be subsequently enlarged by drills.—*Il Politecnico*, from *Rivista Maritima*. C.

Geodesic Accuracy.—Gen. Ibañez communicated to the International Geodesic Congress, at Stuttgart, a statement that by combining the old French angles with those of the late Spanish survey, without any geometric compensation, he obtained a value of 21933·35 m., which differs from the base of Vich, which was measured by him last summer, only 1 decimetre, or less than 4 inches.—*Comptes Rendus*. C.

Nickeled Iron.—The deposit of nickeled iron at Saint Catherine, in Brazil, is now exhausted. It was probably a meteorite with a total weight of at least 25,000 kilogrammes. It was found at a depth of 4 decimetres, under a bed of fragments of coarse-grained granite. Its weight entitles it to one of the first ranks among the known masses of meteoric iron.—*Acad. des Sci.; Les Mondes*. C.

Danger of Speed on Railroads.—Scheffler, in *Organ für die Fortschritte des Eisenbahnwesens*, 1877, Heft v, discusses the influence of speed on the number of railroad accidents. Although he finds four times as many accidents on freight trains as on express trains, and twice as many as on ordinary passenger trains, the slowest trains are not the most dangerous. After making allowance for the distance traveled, the principal kinds of accidents, and other considerations which are requisite for a true basis of comparison, he finds that the danger of bodily accident increases as the square of the speed; and the danger of injury to the track or rolling stock, as the cube of the speed.—*Wochenschrift des Oester. Ing. und Arc. Ver.* C.

Strength of Slate.—Messrs. Blavier & Brossard, mining engineers, have studied the comparative resistance to rupture of the Angers slates, marble, and Tonnerre stone. The experiments were made with slabs of about 1 metre long, ·15 to ·50 metres wide, and ·008 to ·050 metres thick. The rupturing load P was weighed, and the coefficient of rupturing resistance R was calculated by the formula,

$$\frac{P\,(b-a)}{4} = \frac{R\,l\,c^2}{6}$$

in which l is the distance between the supports, b the breadth of slab, c its thickness, and a the breadth of the ledges. The following mean values were found for R: for slate cut lengthwise, 5,621,000; slate cut crosswise, 2,733,000; marble, 1,140,000; Tonnerre stone, 630,400. Slate has the added advantage of being easily split into slabs, while the other stones require the use of a saw.—*Ann. des P. et Chauss.* C.

Parisian Libraries.—The National Library contains more than a half million volumes. Other city libraries aggregate more than 1,100,000 volumes.—*Les Mondes.* C.

Electro-Silicic Light.—M. G. Planté has obtained very brilliant effects by placing one of the poles of a powerful secondary battery in contact with the side of a glass vase or a porcelain basin, holding a saline solution. The luminous appearances observed in glass, under induction currents, by du Moncel, Gassiot, Grove and others, also accompany the new process. The same results may be obtained by substituting rock-crystal for the glass or porcelain, but a higher power is required.—*Les Mondes.* C.

Safety of Railroad Traveling.—The *Annales des Ponts et Chaussées*, for August and September, 1877, contain two valuable articles on the "Block System" of running trains. From the second article we extract the following statistics. The average loss of life in France, in traveling by diligence, was 1 in 355,000; on railroads, from 1835 to 1855, 1 in 2,000,000; from 1855 to 1875, 1 in 6,000,000; from 1872 to 1875, 1 in 45,000,000. A person traveling constantly by railroad, for 10 hours a day, at the rate of 50 kilometres per hour, estimating a mean journey at 30 kilometres, would have had the following chances of being killed by a railroad accident: 1835 to 1855, 1 chance in 321 years; 1855 to 1875, 1 chance in 1014 years; 1872 to 1875, 1 chance in 7459 years. C.

India-Rubber Piston-Packing.—In the "Grands-Makets" Belgian coal mine, there is a cistern, with a direct-acting pump which raises the water to a height of 220 metres. The pump body was lined with metal, and the piston was packed with steel rings. The effective work sank in a few months from 80 to 25 per cent. An examination showed that the steel rings, on account of the impurities of the water, had torn the lining, and broken much of the packing. It was therefore decided to use a softer packing, and copper was tried with similar results. Rings of moderately hard caoutchouc, alternating with copper disks, were then substituted, netting 85 per cent., and avoiding the wear of lining, and consequent diminution of efficiency.—*Dingler's Journal.* C.

Industrial Teaching.—In the school of chemistry, maintained by the Industrial Society of Mulhouse, special attention is paid to the chemistry of colors, and to everything that is connected with dyeing and printing. The first year's course embraces general, mineral and organic chemistry, new products and processes, qualitative and quantitative analysis, preparation of chemical products. In the second year, special attention is given to the aromatic series, to the derivatives of coal tar which are suitable for dyeing textile fabrics, to bleaching, dressing, dyeing and printing, and to the examination of printed tissues, in order to ascertain the colors employed. The course of physics includes heat, optics and electricity, in their industrial applications; the use of the microscope and spectroscope; and such knowledge of mechanics as is indispensable for understanding the operation of machinery. The pupils visit industrial establishments, accompanied by their professors. In the school of spinning and weaving, both theoretical and practical instructions are given in designing; in the manufacture of various threads and tissues; in the study of new and improved machinery and models; in the different transformations of motion, force and work; in steam and hydraulic motors and apparatus; in heating apparatus and combustibles; in book-keeping, and in the analysis of tissues. C.

American Steam-Boilers.—The Austrian Commissioners to the Centennial Exposition are preparing very complete accounts of the several departments. From Prof. Radinger's descriptions of the steam-boilers, *Il Politecnico* extracts some interesting comments.

The height of the American chimneys varies from 20 to 60 metres; the section of escape is made from $1\frac{1}{3}$ to $1\frac{1}{4}$ times the mean section of the smoke-pipes, and is often calculated according to the following formula:

$$A = \frac{112\,N}{\sqrt{H}}, \text{ or } A' = \frac{4\,N}{\sqrt{H'}},$$

in which A, H and N represent, respectively, the section of the chimney in square inches, the height in feet, and the force of the boiler in horse powers; A' and H' represent the section and height in square decimetres and metres. The formulæ accord very closely with those of Redtenbacher and Darcet. About 100,000 boilers are used in the United States, of which about 80,000 are subject to no kind of official inspection. Explosions are frequent, due for the most part to the negligence of firemen, and to the adoption, by patentees, of objectionable forms, which render proper cleaning almost impossible. Among the tubular generators, that of Pierce is noticed, "which is the realization of one of the most curious ideas that ever sprouted in an American brain." The Corliss boiler is noteworthy for its simplicity and compactness. It might profitably be imitated in all cases where economy of space is a *sine qua non*. The dryness of its vapor is an added advantage. C.

Strength of Iron at Different Temperatures.—G. Pisati and G. Saporito-Ricca find that the strength of iron at different temperatures shows peculiar irregularities. The strength, in a wire which is exposed to a dull-red heat, diminishes with increase of temperature from 14° to 50°, then increases to 90°, diminishes rapidly to 120°, remains constant to 200°, sinks slowly to 235°; then comes a sudden increase, which is followed by a gradual diminution. The strength is greater at 300° than at 140°.—*Pogg. Ann.; Dingler's Journ.*, 225, 512. C.

Brachy Telescope.—J. Forster and K. Fritsch describe, in *Dingler's Journal*, 226, 3, a combination of two reflectors with eye-glasses, which they call a brachy telescope, uniting the advantages of Herschel's and Cassegrain's telescopes. With a mirror of 106 millimetres diameter, Fritsch has seen the double star γ Virginis, β Orionis (Regulus), η Pleiadum (Atlas), the Pole-star, and others, beautifully separated. C.

Researches in Feeble Magnetism.—P. Silow reports results of his investigations in the laboratory of Prof. Helmholtz, for determining the absolute value of the magnetizing constant of fluids. He starts from the considerations, that the study of strongly magnetized bodies shows the insufficiency of Poisson's hypothesis; that the ratio of polarizing to magnetizing power is independent of the latter, and is of a constant magnitude; and that in weakly magnetized bodies, especially in fluids, only a temporary polarization occurs He refers to the researches of W. Weber, Toepler and v. Ettingshausen, and G. Wiedemann, as confirming Poisson's first hypothesis, and as establishing laws relative to the influence of the magnetizing power, of the concentration, of the solvent, etc. He admits that the deviation of some of the results from the mean is considerable (in one instance ·138), but considers them satisfactory in view of the delicacy of the measurements.—*Ann. d. Phys. u. Chem.*, 237, 481, *seq.* C.

New Electrical Law.—Clausius announces the following general law, of which many of the known laws of electrical reciprocity are immediate consequences: Suppose any number of conductors, C_1, C_2, C_3, which neutrally influence each other. Let them be charged with electricity in two different ways; at the first charge, let the respective quantities in the different bodies be Q_1, Q_2, Q_3, etc., and the resulting potential levels V_1, V_2, V_3, etc. At the second charge let the corresponding values be $\mathfrak{Q}_1$, $\mathfrak{Q}_2$, $\mathfrak{Q}_3$, etc., $\mathfrak{V}_1$, $\mathfrak{V}_2$, $\mathfrak{V}_3$, etc. Then we shall find:

$$V_1 \mathfrak{Q}_1 + V_2 \mathfrak{Q}_2 + V_3 \mathfrak{Q}_3 +, \text{ etc.}, = \mathfrak{V}_1 Q_1 + \mathfrak{V}_2 Q_2 + \mathfrak{V}_3 Q_3 +, \text{ etc.};$$

or, taking the sums, $\Sigma V \mathfrak{Q} = \Sigma \mathfrak{V} Q$.—*Ann. d. Ph. u. Ch.*, 237, 493. C.

Electric Conductivity in Constant Streams.—F. Kohlrausch and O. Grotrian (*Pogg. Ann.*, cliv and clix) have found values for the electric conductivity of fluids with variable streams. J. Tollinger has experimented with nine different solutions in constant streams. The percentage of the soluble ingredient varied between 2·5 and 94·5; the resistances, between 27·96 and 255·47. The differences in the results, as measured in constant and in variable streams, range between ·1 and 1·3 per cent.—*Ann. d. Ph. u. Ch.*, 237, 514. C.

Fire-Proof Flooring.—An English brewer made his malt-floor of three-inch planks grooved together. A fire broke out, the roof over the floor fell in, and the fire raged for twenty-four hours over the floor without burning through it, because the grooves prevented a supply of air from below. The security might be increased by covering the beams and the under side of the planking with fire-proof cement.—*Der pr. Masch.-Const.* C.

Variability of Orbital Major-Axes.—M. S.-C. Hareter finds that the invariability of the major-axes of planetary orbits, which Laplace, Lagrange and Poisson have established for the first and second powers of the disturbing masses, does not hold for higher powers. It may, therefore, perhaps, be found that the stability of the system requires the figurate harmony of principal planetary masses, which was pointed out in the September number of this JOURNAL, page 148.—*Comptes Rendus.* C.

Apparatus for Measuring the Work of Iron.—In the *Annales des Ponts et Chaussées* for October, 1877, M. Dupuy describes some new apparatus for the direct measurement of the work of iron, the need of which was suggested by the increasing number of iron bridges. The system rests on the fact that a bar of iron, 1 metre long, stretches or shortens to the extent of one-tenth of a millimetre for a tension or compression of two kilogrammes per square metre of section. The apparatus requires great care in its use, and it should only be intrusted to conscientious and intelligent experimenters, but when such precautions are taken as are obviously necessary, it seems likely to yield valuable results. The experiments that are reported in the paper show a close accordance with theory. The theoretical maxima were never surpassed. C.

Removal of Grease from Feed-Water.—M. Hetet uses lime-water to fix the fatty acids in the feed-water of boilers in engines with surface condensers. The corrosive action of such acids rapidly wears out the boilers, and the greasy water cannot be made potable by distillation. M. Hetet's method has been introduced on many vessels of the French navy, and he claims that it adds greatly to the duration of the boilers, while it furnishes a distilled water without odor and without taste, and entirely unobjectionable for drinking or for cooking.—*Comptes Rendus.* C.

Condensation in Steam Cylinders.—In the *Ann. des Mines*, Pt. 3, for 1877, M. Ch. Ledoux discusses the condensation of vapor in the cylinders of steam engines. He claims that his method gives a sufficient practical approximation for each of the following estimates:

1. The weight of the mixture of steam and water furnished by the boiler at each stroke of the piston, the proportion of water carried over by the steam being known.

2. The proportion of suspended water, when the total weight of feed-water is known.

3. The consumption, in *calories*, for a given amount of work, or the true industrial measure of the utilization of steam.

4. In a locomotive, the quantity of water vaporized by the boiler during a given time, and the resulting power of traction at a given velocity.

C.

St. Gothard Tunnel.—At the northern opening granitic beds have been encountered, and at the southern end abundant springs of water. These difficulties have been completely surmounted. The Italian journals anticipate the completion of the work by the spring of 1880, provided the necessary funds are raised.—*Les Mondes.*

C.

Book Notice.

THE TELEPHONE; AN ACCOUNT OF THE PHENOMENA OF ELECTRICITY, MAGNETISM AND SOUND INVOLVED IN ITS ACTION. With directions for making a Speaking Telephone. By Prof. A. E. Dolbear. Lee & Shepard, Boston.

The intent of this little manual is set forth in its preface: "The popular exhibition of the speaking telephone during the past six months, together with numerous newspaper articles, have created a widespread interest in the instrument; and it has been thought that a small book, explanatory of its action, would meet a public want."

After a hasty, yet lucid, sketch of the discoveries in Electricity, Voltaic Electricity, Magnetism and Electro-magnetism, a chapter is devoted to the *theories* of electricity. The fundamental laws regulating sound are then explained. The "Correlation" of sound and electricity is demonstrated. The book concludes with a description of different telephones.

On describing the telephone of Prof. Bell, no other description is given than of one working by means of *electro-magnetism*. The recent improvement in Bell's telephone, of substituting permanent bar magnets for electro-magnets, is not referred to.

The author claims to have been the inventor of the speaking telephone "in which *magneto-electric* currents were utilized for the transmission of speech and other kinds of sound." If such a claim can be substantiated, the little manual does not make its appearance any too soon in contesting the association, by the public, of the name of Prof. Bell with the telephone, as claimed by the author.

We would recommend the book as a pleasantly written popular treatise on this "marvel in electric telegraphy." B.

Franklin Institute.

HALL OF THE INSTITUTE, Dec. 19th, 1877.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 119 members and 19 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 10 persons were elected members of the Institute, and the following donations were made to the Library:

Brief Inquiry into the principles, effects, etc., of the American Patent System. By H. & C. Howson, Phila. 4th Edition.

Illustrated account of the fire in the U. S. Patent Office Building, Sept. 24th, 1877. From H. & C. Howson, Phila.

Mahan's Industrial Drawing; comprising the description and uses of drawing instruments, etc. From J. Wiley & Sons.

List of writings relating to the method of least squares. By M. Merriman. From the Author.

Report of the Meteorological Committee of the Royal Society for seventeen months ending May 31st, 1877. From the Society.

Minutes of Proceedings of the Institution of Civil Engineers. Vol. 50. Session 1876–77. Part 4. London, 1877. From the Institution.

Polar Colonization. The preliminary Arctic expedition of 1877.

Annual report of the Secretary of War, for the fiscal year ending June 30th, 1877. Washington, 1877. From the Secretary.

State Agricultural College of Michigan, 1877, Twenty-first annual Catalogue of Officers, etc. From the College.

Report of the Superintendent of the U. S. Coast Survey, showing the progress of the survey during 1874. Washington, 1877. From the Superintendent.

Report of the Committee on Restoration of Independence Hall, 1873. From E. Hiltebrand.

A test for determining the position of a partial discontinuity without earth fault. By W. E. Ayrton and John Perry. From the Authors.

Annual report of the Surgeon-General, United States Army, 1877. From the Secretary of War.

Programm der Grossherzoglich Zadischen Polytechnischen Schule zu Carlsruhe fur 1877–78. From the School.

Memoirs of the Geological Survey of India. Vol. 13.
Palæontologia Indica. Ser. 2, 2. Jurassic flora of the Rajmahal Group. From the Survey.

Uber Oesterreichische Mastodonten und ihre beziehungen zu den Mastodonarten Europas, von M. Vacek. Wien 1877. From the K. K. Geol. Reïchsantstalt.

Report upon the U. S. Geographical Surveys west of the one hundredth meridian; Lieut. Wheeler in charge. Vol. 4, Palæontology. Washington, 1877. From the Chief of Engineers.

The Secretary presented his report, embracing Marcy's sciopticon, triple jet, and automatic cut-off; Hoyle's paper fastener and stamp; Chambers Bros. & Co.'s bolt and rivet clipper; and Norcross's governor for hot air furnaces.

On motion, the consideration of the amendments to the By-Laws, proposed at the last meeting, was postponed to the stated meeting in January next.

Mr. J. E. Mitchell offered the following, which was laid over under the rules:

Resolved, That the By-Laws be amended by striking out of Sec. 5, of Art. II, the words "on the payment of one dollar," and striking